Research Paper

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Carbon Risk and Resilience
How Energy Transition is Changing the Prospects for Developing Countries with Fossil Fuels

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Contents

Executive Summary

International climate commitments and the global shift towards a decarbonized economy are challenging tried and tested models of development. This presents serious risks and opportunities for countries like Ghana, Tanzania, Guyana and Mozambique, where there are hopes that fossil fuel discoveries will transform their economies. Drawing on discussions with national governments, multilateral development banks (MDBs) and donor agencies, and a series of modelled scenarios, this paper sets out how carbon risk – defined in this paper as the economic risks associated with dependence on or exposure to high-carbon sectors – will affect developing countries with fossil fuels in the coming decades. It also makes recommendations for governments and their development partners that should enhance economic resilience and competitiveness throughout their transition.

Meeting the long-term goal of the Paris Agreement – limiting the increase in the global average temperature to 'well below 2°C above pre-industrial levels' and pursuing efforts to limit the temperature increase to 1.5°C – will have profound implications for fossil fuel markets. Even where optimistic assumptions regarding the deployment of carbon capture and storage (CCS) and negative emissions technologies (NETs) are made, a rapid decline in global fossil fuel demand is needed in order to remain within a 2°C scenario. The least-cost pathway to this goal would be for coal demand to fall immediately, oil demand to slow from the mid to late 2020s, and natural gas to decline from the mid-2040s. This, in turn, would leave over 80 per cent of global coal reserves, half of gas and one-third of oil undeveloped.

The global context for fossil fuel investment is already changing rapidly. The investment and finance communities are watching for signals of the trends that will affect the speed and shape of the global energy transition – from reforms to fossil fuel subsidies and the introduction of carbon pricing, to the falling cost of renewable energy (RE) and storage technologies, and rising electric vehicle (EV) uptake. They are increasingly looking to reduce their exposure to high-carbon assets and investments that will decline in value throughout the transition, and anticipate policy shifts at country-level that might alter the relative competitiveness of low-carbon technologies and services. Central banks and regulators are considering how these trends might pose a risk to financial stability, while the G20 has raised these issues on the international agenda via the Task Force on Climate-related Financial Disclosures (TCFD).

These dynamics fundamentally change the prospects for developing countries that hope to use fossil fuels as a 'leading sector' for growth. Tightening climate policies, fossil fuel investment and RE trends suggest that the cost curves for commercially viable oil and gas projects are changing, and that the time frame for profitable production will be limited. This raises the potential for 'stranded' upstream investments and undeveloped fossil fuel resources, which could impose high opportunity costs on lower-income countries. At the same time, over half of the world's least developed and lowest income countries are currently planning to explore for fossil fuels or expand their existing production, and use the associated revenues and fuel supply to help drive their economic development. Their strategic choices will affect the lives of over 1.6 billion people, as well as the chances of staying within a 2°C carbon budget.

Making long-term decisions on fossil fuel development and associated energy and industrial infrastructure amid such uncertainty presents a huge challenge for these governments, and one in which international development assistance plays an influential role. MDBs and donors have committed at least $28 billion in finance and guarantees to upstream fossil fuels and thermal power generation between 2010 and 2015. By providing concessional finance and investment guarantees, they help de-risk and lower the cost of capital, encouraging much larger sums of private capital into the sector. Now they are shifting their focus to climate finance and green growth in line with the Paris Agreement, which committed richer countries to mobilize $100 billion a year in climate finance for developing countries from 2020. As MDBs scale up their climate finance commitments – which reached a combined $32 billion in 2017 – they are also beginning to reform their policies towards fossil fuels. The World Bank Group has announced that it will stop financing upstream oil and gas by 2019.

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Better alignment between development assistance to fossil fuel sectors and climate finance and support for low-carbon development and green growth is critical to supporting inclusive and resilient growth. The development of fossil fuels and related power and industrial infrastructure is a multi-decade undertaking, which will heavily influence a country's future economic development and energy systems. As international investment and development assistance move away from fossil fuels and towards clean energy, developing countries with fossil fuels will need timely information and new approaches to managing risk. This paper explores some of the challenges that developing countries with fossil fuels face, and how their governments and development partners can respond, through the following questions:

- How might decarbonization affect developing countries with fossil fuels and change the nature of traditional 'resource curse' risks, and how can scenarios help explore the impacts of this (drawing on modelled examples for Ghana and Tanzania)?
- At the country level, what policy measures and practical responses can help governments assess carbon risks and align fossil fuel sector decision-making with long-term climate and green growth goals?
- At the international level, how are MDBs and donors responding to these trends, and where are there opportunties to improve policy coherence and coordination around carbon risks and better support transition in fossil fuel driven economies?

Key findings and recommendations

Developing new approaches to carbon risk

Companies, investors, central banks and regulators are increasingly testing their long-term resilience against 2°C scenarios. Compared to current Nationally Determined Contributions (NDCs) under the Paris Agreement, 2°C scenarios suggest a much smaller role for fossil fuels. However, major uncertainties regarding the expansion of CCS and the evolution of clean technologies mean they cannot be taken as a reliable guide to the future. Long-term investors (including pension funds and sovereign wealth funds) are responding to this, increasingly limiting or excluding fossil fuels from their portfolios and using their shareholder votes to influence company behaviour. These trends are already having an impact on the direction of international oil companies (IOCs) and publicly-traded national oil companies (NOCs) such as Equinor in Norway and (soon-to-be-listed) Saudi Aramco in Saudi Arabia, and may in time affect sovereign debt.

For developing countries that are considering exploring for oil and gas or expanding existing production, multi-decade scenario analysis that considers the interaction between production, revenues and demand under different climate outcomes can help improve decision-making and reduce exposure to carbon risks. The country scenarios to 2045 developed for this paper show a wide range of revenues under different climate constraints. Ghana's oil revenues could vary by around 50 per cent between an NDC and a 2°C No CCS scenario, while Tanzania's gas revenues could vary by around 80 per cent, reflecting the greater impact of accelerating RE and lower than anticipated levels of CCS in the power sector. Lower than anticipated or sharply declining revenues may compound many traditional fiscal challenges that fossil fuel producers tend to face, particularly the strain that rising domestic fuel demand places on foreign exchange. 'Greening' domestic demand could help mitigate this stress, as well as support the delivery of NDCs.

Changing patterns of demand for fossil fuels would also affect the window of opportunity for economic diversification away from the sector – widely considered the litmus test for 'successful' fossil fuel-led growth. Compared to the traditional lifespan of an oil or gas resource, which may span several decades and offer the opportunity to re-invest and extend the 'plateau' in production, the most constrained climate scenarios suggest a much tighter time frame for diversification. While the NDC and 2°C scenarios show Tanzania's gas exports continuing for over two decades, the 'No CCS' 2°C scenario shows it declining from 2030 and potentially leaving infrastructure stranded and fossil fuel resources undeveloped, assuming development proceeds at all. This highlights the dependence of national plans on fossil fuel supply and the level of infrastructure development and investment (or debt) required to deliver this as key contributors to carbon risk at the country-level.

> Carbon-related shifts in energy investment and demand patterns are likely to act as risk multipliers for many well-known resource curse risks.

Carbon-related shifts in energy investment and demand patterns are likely to act as risk multipliers for many well-known resource curse risks. However, their economy-wide implications remain poorly understood and largely unprepared for. Countries could address this by:

- **Building understanding of a country's exposure to carbon risks and its time frame for transition through the development of multi-decade scenario analyses.** These should consider the interaction between production, revenues and demand under different climate constraints, including 'worst-case' scenario for fossil fuel investment and demand. While such scenarios will always be imperfect, the process of developing them can help identify the nature of carbon risk between the fossil fuel sector and the wider economy, including the potential range of revenues and the time frame for production. MDBs and development agencies can help support the development of replicable, analytical approaches and build country capacity to utilize them.

- **Developing economy-wide approaches to carbon-related risks and opportunities for green growth, alongside the development of NDCs and long-term low greenhouse gas emission development strategies to 2050 under the United Nations Framework Convention on Climate Change (UNFCCC) process.** Countries at an earlier stage of exploration or production may have the opportunity to avoid entrenching high-carbon dependence through their initial decisions regarding revenue and fuel deployment and infrastructure investment. Where fossil fuel production is already underway, the focus is likely to be on developing policies and mechanisms to mitigate carbon risk and support low-carbon transition as part of sustainable economic diversification.
- **Where capacity permits, establishing a cross-government 'transition dialogue' to scope the country-specific carbon risks and opportunities that a decarbonizing world presents.** This could focus on economy-wide implications, from the energy and industrial pathways that fossil fuel development might lock-in to fiscal stability implications (including the sustainability of debt) and impacts on the wider investment environment for climate finance and for the country's broader economy. This could be championed at cabinet level, and bring together stakeholders from government institutions related to finance, national planning, energy and power, environment and climate, and oil and gas, among others.

Building country capacities for transition

The impact of these carbon risks over time will of course vary depending on a country's stage of fossil fuel production, the type and scale of resource, its cost of production and, crucially, the planned allocation of production to export and domestic markets. The proposed role of fossil fuel revenues and/or physical fuel flows in the national economy, and the kinds of carbon linkages these establish – through the spending and investment of revenues and through the development of energy and industrial systems – is a major variable between countries, particularly where gas is concerned. The challenges confronting Tanzania and Mozambique, where most gas production will be exported, look very different to those in Ghana, where gas production will supply the domestic power sector.

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The choices that emerging and early-stage producers face differ from those of their more established peers. They include an opportunity to develop along a greener, lower-carbon path from the outset and avoid the need for expensive transition later on. For example, a small country like Guyana, which is just embarking on large-scale offshore oil production, will have options not available to populous, established oil producers with significant domestic fossil-fuel demand such as Nigeria and Angola. Countries deciding whether to explore for fossil fuels or develop their discoveries should consider how associated revenues and fuel flows – and the infrastructure they require – might support or undermine national green growth ambitions and the delivery of increasingly ambitious NDCs over time.

Developing capacities in leading institutions and policy areas – including economic governance, energy and industrial policy, and the fossil fuel sector – can enhance a country's ability to effectively manage carbon risk and support transition. Countries and their advisers should review traditional 'good governance' recommendations relating to fiscal governance, upstream oil and gas, and energy and industrial planning with carbon risks in mind, for example:

- **Developing 'carbon risk competencies' in key areas of economic governance.** Central banks and ministries of finance and those who manage revenues have an important role to play in three key areas: first, assessing the implications of the energy transition for domestic fiscal stability and the time frame for diversification; second, reviewing revenue management frameworks in light of their vulnerability to carbon risks and their potential to support domestic transition and NDC implementation; and third, investing sovereign wealth funds (SWFs) in a way that avoids 'double' exposure to high-carbon international assets and helps hedge the overall national balance sheet from shocks.
- **Designing energy and industrial policy to incentivize transition.** Getting policy, regulation and pricing right is crucial to a country's attractiveness for finance and technology transfer. Adopting integrated approaches to upstream, energy and climate planning can help identify the 'lowest-cost' pathway to delivering energy access and industrialization goals, and as well as the most flexible infrastructure options and the ideal balance between on- and off-grid power supply over time. Governments should seize the opportunities that urbanization and green industrialization trends present to 'shape the peak' in emissions through smart urban design and demand-side management.
- **Preparing the fossil fuel sector for transition.** With the right incentives and capacities, institutions that manage and operate in the upstream – including ministries of energy and power, upstream regulators and national oil companies (NOCs) – can help manage carbon and emissions. Building capacity to procure clean technologies, monitor and manage emissions and apply carbon pricing to analysis and decision-making could contribute to this. The establishment and appropriate mandate of an NOC should be carefully considered in light of the likely time frame for transition. Peer-to-peer learning between lower-capacity and more established producers on technical issues and long-term strategy may help.

Aligning development assistance with climate and country needs

As MDBs and development agencies scale up their climate finance and support for green growth, policy and technical advice will need to engage with the unique challenges that developing countries with fossil fuels face. Effective support requires understanding of politically-viable alternative development models or support for transition pathways that account for existing fossil fuel interests and exposure to carbon risks. Sharing experience and best practice across agencies could help speed up this learning curve. For example, the European Bank for Reconstruction and Development (EBRD) supports the TCFD and is integrating 'transition risk' into its advice to fossil fuel-driven economies, while the African Development Bank (AfDB) is working to mainstream 'climate-resilient growth' and NDC implementation into its assistance to countries with fossil fuels.

These approaches must be grounded in developing country perspectives, and their anticipated support for climate mitigation and adaptation. Should developing countries focus on fossil fuel development and building large-scale, capital-intensive fossil fuel infrastructure instead of reaping the competitive advantages that clean technologies, green urbanization and industrialization and smart, circular economy systems offer, they risk being burdened with much higher costs for low-carbon transition in the coming decades, in addition to the costs of adaptation and loss and damage associated with climate impacts. The following steps will assist partner countries in making the right decisions. Key recommendations for donors and MDBs include:

- **Aligning development assistance to upstream oil and gas and linked energy and industrial infrastructure country NDCs and long-term emissions reduction plans to 2050.** Where fossil fuel development is under consideration, MDBs and donors should support country studies to explore whether this is compatible with national climate ambitions, and allows scope for NDCs to become increasingly ambitious over time. Where support to fossil fuels is made on the basis of its contribution to NDC targets – for example gas-to-power in order to displace coal- and diesel-generation – development partners must be prepared to support the wider investment and capacity to effectively deliver this outcome. Where it conflicts with a country's NDC and wider green growth objectives, development assistance for alternative energy systems and economic activities should be coordinated.
- **Developing clear and consistent policy positions on the re-alignment of development assistance in support of the Paris Agreement, alongside private sector partners.** Policy should address the conditions for support to upstream fossil fuels and linked downstream energy and industrial activities under a 2°C scenario, as well as common approaches to the use of carbon pricing. MDBs can provide credit enhancements and package bankable projects to crowd-in private finance into infrastructure that enables a low-carbon, climate resilient pathway. At the national level, donor countries should ensure that the activities of other forms of public finance, including non-ODA policy banks and export credit agencies (ECAs), do not conflict with their development agency objectives.
- **Enhancing policy coherence at the international level.** There is a risk that assistance from different actors will support conflicting development models, further damaging prospects for sustainable growth. This makes deepening cooperation with non-traditional donors – and particularly the Asian MDBs, policy banks and ECAs, which provide the vast majority of finance for high-carbon sectors – even more important. Given its role in furthering international cooperation on climate-related financial risk and green finance, the G20 could support dialogue between G20 members (and other key donors such as Norway), participating MDBs and international organizations, and non-participating developing countries, with the objective of coordinating development assistance around these issues. This could also help provide a framework for North–South and South–South lessons-sharing and capacity-building.

1. Introduction

Countries developing oil and gas today cannot expect to follow the same fossil fuel-led development model that has underpinned growth in many upper-middle and high-income countries over the last half century, including Norway, the UK, Saudi Arabia, Mexico, Kazakhstan, and Trinidad and Tobago. Two major new challenges to a fossil fuel-led development pathway have emerged in recent years:

- First, tightening climate and air quality policies and the collapsing cost of clean energy technologies in major consumer markets such as the EU and China, and their implications for global fossil fuel demand. Shifting global investment patterns are now accelerating these shifts.
- Second, rising ambition among developing countries looking to follow a 'greener' energy and industrial pathway and benefit from low-carbon opportunities and climate finance. The experience of established and emerging exporters including Nigeria, Angola and Ghana following the oil price collapse of 2014 has heightened interest in sustainable economic diversification.

This paper considers how these challenges might affect the development prospects of low and lower-middle-income countries with fossil fuel resources, both in terms of carbon risks and low-carbon opportunities. It also addresses the challenges faced by multilateral development banks (MDBs) and international donors that offer development assistance to upstream fossil fuel projects and linked power and industrial infrastructure, while at the same time making international climate change commitments. Based on the findings of dialogues with country stakeholders, and the MDB, donor and investment communities, and global and country-level modelling, this paper suggests ways that developing countries with fossil fuels might best enhance their resilience to carbon risks and benefit from low-carbon opportunities throughout the energy transition, and how MDBs and donors can support this.

The changing global context for fossil fuel-led growth

The convergence of three major trends – growing global and national climate action, the increasing range and falling cost of clean energy technologies and the relative decline in oil prices – present a rapidly evolving landscape for emerging and early-stage fossil fuel producers. These trends provide the context for this paper.

Climate policy and future fossil fuel supply

Markets for fossil fuels will be profoundly affected by climate, environment and energy-related policies in major consuming countries. Donors and MDBs (and their partner countries) are all committed to the 'well below 2°C' target of the Paris Agreement.[1] The concept of the global 'carbon budget' – or the amount of carbon that can be emitted under any given temperature target – has direct implications for future fossil fuel supply. The burning of coal, oil and gas is responsible for over 65 per cent of greenhouse gases.[2] In 2015, University College London (UCL) attempted to show how a '2°C carbon

[1] UNFCCC, (2016), *The Paris Agreement*, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (accessed 30 May 2018).
[2] IPCC (2014), *Climate Change 2014: Mitigation of Climate Change*, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, http://www.ipcc.ch/report/ar5/wg3/ (accessed 30 May 2018).

budget' might be distributed between regions on a 'least-cost' basis, as a first attempt to map the likely landscape of 'burnable' and 'unburnable' fossil fuel reserves.[3] It showed that in order to meet the long-term goal of the Paris Agreement, over 80 per cent of the world's proven coal reserves, half of its gas and one-third of its oil would need to remain unburned.[4]

As documented in an earlier Chatham House research paper*, Left Stranded? Extractives-Led Growth in a Carbon-Constrained World*, the prospect of unburnable fossil fuels presents clear risks to export economies.[5] Which raises the question, is it prudent to develop fossil fuel resources for which there may be less or no demand, as fossil fuel consumption peaks and declines? While the time frames for this are unclear, and the impacts will differ by fuel and by region, the overall consensus is that a combination of climate and air quality policies, fuel price reforms and clean technology developments in key export markets will significantly reduce demand for fossil fuel imports over time. Chapter 2 sets out some of the key uncertainties at the global level, and the way the investment and finance communities are responding to them. Chapters 3 and 4 explore how these trends might translate into challenges at the producer country level, drawing on modelled scenarios for Ghana and Tanzania. More recently, researchers have explored policy options to 'limit' future fossil fuel supply[6] and the equity implications of the global carbon budget.[7] These are discussed in greater detail in Chapter 5.

Box 1: Why coal presents a special case

This paper re-states the urgent need for coal phase-down. Chapter 2 acknowledges the interplay between coal phase-down and the prospects of other fossil fuels, particularly gas. However, in its discussion of carbon risks and opportunities, and their implications for country planning, this paper concentrates on oil and gas projects and linked power and industrial infrastructure. It does not consider coal projects in any detail, for two main reasons:

- Coal has accounted for less than 0.25 per cent of reported official development assistance (ODA) to energy since 2010, and most traditional MDBs and donors have refused to support coal projects since 2013, when the World Bank announced that it would only support coal projects under exceptional circumstances. Current investment in coal supply and generation is dominated by ECAs, Asian policy banks and other forms of public finance, which largely fall beyond the scope of this paper.[8]
- Compared to oil and gas, coal projects have very different economic, societal and environmental impacts. Less than one-quarter of coal is internationally traded, and it provides much lower 'rents' to central government. It also has higher transport infrastructure and local (direct and indirect) employment footprints, and public health and environmental impacts.

[3] McGlade and Ekins (2015) provided the first region-by-region distribution of fossil fuel supply within a 2°C carbon budget, on the basis of 'least-cost' production and transport i.e. the lowest-cost means of meeting demand remains in production the longest.
[4] McGlade, C. and Ekins, P. (2015), 'The geographical distribution of fossil fuels unused when limiting global warming to 2°C', Letter, *Nature*, Vol. 51, doi:10.1038/nature14016, https://www.nature.com/articles/nature14016 (accessed 30 May 2018).
[5] Lahn, G. and Bradley, S. (2016), *Left Stranded? Extractives-Led Growth in a Carbon-Constrained World,* Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/sites/files/chathamhouse/publications/research/2016-06-17-left-stranded-extractives-bradley-lahn-final.pdf (accessed 30 May 2018).
[6] Piggot, G., Erickson, P., Lazarus, M., and van Asselt, H. (2017), *Addressing fossil fuel production under the UNFCCC: Paris and beyond*, SEI Working Paper, Stockholm Environment Institute: Stockholm, https://www.sei.org/mediamanager/documents/Publications/SEI-2017-WP-addressing-fossil-fuel-production.pdf (accessed 30 May 2018); Verkuijl, C., Piggot, G., Lazarus, M., van Asselt, H. and Erickson, P. (2018), *Aligning fossil fuel production with the Paris Agreement: Insights for the UNFCCC Talanoa Dialogue*, Policy Brief, Stockholm Environment Institute: Stockholm, https://unfccc.int/sites/default/files/resource/11_12_13__SEI_Talanoa_Fossil_Fuels_0.pdf (accessed 30 May 2018).
[7] See, for example, Kartha, S., Caney, S., Dubash, N. K. and Muttitt, G. (2018), Whose Carbon is Burnable? Equity considerations in the allocation of a 'right to extract', *Climate Change*, 24 May, https://doi.org/10.1007/s10584-018-2209-z (accessed 31 May 2018).
[8] China, Japan, Germany and South Korea provide the vast majority of finance to overseas coal projects. See Chen, H., Doukas A., Schmidt J., and Vollmer, S. L. (2016), *Carbon Trap: How International Coal Finance Undermines the Paris Agreement*, Natural Resources Defense Council and Oil Change International, https://www.nrdc.org/sites/default/files/carbon-trap-international-coal-finance-report.pdf (accessed 30 May 2018); Doukas, A. DeAngelis, K. and Ghio, N. (2017), *Talk is Cheap: How G20 Governments are financing Climate Disaster*, Oil Change International, Friends of the Earth U.S., the Sierra Club, and WWF European Policy Office, http://priceofoil.org/content/uploads/2017/07/talk_is_cheap_G20_report_July2017.pdf (accessed 30 May 2018).

The changing range and cost of clean technologies and green growth opportunities

Many countries have benefited from developing their fossil fuel resources. Development models like those of the Gulf, Trinidad and Tobago, and Malaysia all provide compelling examples of fossil fuel-led growth that many less-developed countries are keen to follow. At the same time, however, fossil fuel producers in the developing world are increasingly embracing the concept of climate-smart, 'green' growth. They have made commitments to mitigate carbon emissions through their initial Nationally Determined Contributions (NDCs) under the Paris Agreement, which cover the period 2020–25, and plan to increase this ambition every five years under the 'ratchet' mechanism of the Paris Agreement.[9] The development of long-term emissions reductions plans to 2050 under the United Nations Framework Convention on Climate Change (UNFCCC) will help guide this.[10]

The concrete policy measures that are required for the implementation of these ambitions generally entail reforms in the energy, transport and forest sectors. Stated measures in the NDCs of low and lower-middle-income fossil fuel producers such as Ghana, Uganda, Tanzania and Kenya include:

- **Energy –** diversifying the energy mix; increasing use of RE; the promotion of energy and resource-efficient technologies; clean household lighting and cooking; rural electrification.
- **Transport** – reform of petrol/diesel subsidies; air quality regulations and reduction of urban congestion; efficient mass transportation systems; long-term transport policy.
- **Forests –** large-scale afforestation/reforestation; use of clean-energy sources and technology to reduce reliance on wood fuels; sustainable use of forest resources via the UN's Reducing Emissions from Deforestation and forest Degradation (REDD+) programme.[11]

Access to RE, storage and other clean technologies will be key to delivering many of these ambitions. In many developing countries with low levels of access to electricity and a heavy reliance on diesel generators, decentralized RE already provides the cheapest access to energy. Competitive procurement through RE auctions, for instance, is now driving down the costs of utility-scale RE in key markets. In India, for example, new wind and solar generation is now cheaper than around two-thirds of the country's coal-fired generation, and costs are continuing to fall.[12] Recent research from the International Renewable Energy Agency (IRENA) suggests that globally, utility-scale RE will be competitive with or cheaper than fossil fuel generation by 2020.[13] Since 2015, developing economies (including China, India and Brazil) have dominated the record sums of money being invested in RE systems.[14]

Such rapid shifts in the global energy landscape raise serious questions for country decision-makers. As global energy systems, trade flows and investment patterns change, and with related changes in the cost curve for different energy technologies, is the development of high-carbon industries, followed by a period of economic diversification still the best pathway?

[9] Under the Paris Agreement, countries have committed to reviewing their NDC commitments every five years, and incrementally raising their ambition through a 'facilitative dialogue', the first of which begins in 2018.
[10] UNFCCC (2018), *Communication of long-term strategies,* http://unfccc.int/focus/long-term_strategies/items/9971.php (accessed 30 May 2018).
[11] UNFCCC (2018), *NDC Registry (interim)*, http://www4.unfccc.int/ndcregistry/Pages/Home.aspx (accessed 30 May 2018).
[12] Greenpeace India (2017), 'Replacing India's Expensive Coal Plants with Solar and Wind Could Save Billions, Analysis Finds', https://unearthed.greenpeace.org/2018/01/05/india-solar-wind-air-pollution-coal/ (accessed 1 May 2018).
[13] IRENA (2018), *Renewable Power Generation Costs in 2017*, International Renewable Energy Agency: Abu Dhabi, January 2018, https://cms.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.ashx (accessed 30 Jun. 2018).
[14] Investments in green energy have surpassed $240 billion per year for eight consecutive years. See Frankfurt School-UNEP Centre/BNEF (2018), Global Trends in Renewable Energy Investment 2018, http://www.fs-unep-centre.org (accessed 30 May 2018).

National policies, plans and investments in the fossil fuel sector and linked energy, industrial and transport infrastructure are rarely coordinated with clean technology investments or wider climate commitments, and may even conflict with them. As noted earlier, the development or expansion of fossil fuels in developing countries (or even the expectation thereof) can affect the political economy, and the concentration of political power and institutional development in a country, leading to the over-dependence of state budgets on investment flows and export revenues from the fossil fuel sector. This is often coupled with overblown societal expectations about the benefits the sector can provide (in terms of infrastructure, employment and wider economic impetus).[15] Structural features that emerge in fossil fuel economies include cheap or subsidized fossil fuel energy and inputs and the development of carbon-intensive infrastructure, as well as strong political interests that tend to gather around the influence and profits associated with the sector; all have the potential to complicate the development of a low-carbon economy.[16]

The end of the 'boom-bust' era?

The above trends come at a time in which country politics and economics are being shaped in response to the commodities price collapse of 2014.

Emerging economies that had enjoyed high GDP growth rates over the previous decade, such as Angola and Nigeria, suffered severe economic shocks as oil and gas prices dropped.[17] Facing balance-of-payments pressures as foreign direct investment (FDI) dried up and commodity prices collapsed, many governments were forced to make spending cuts, raid foreign exchange reserves or continue to borrow to stay afloat, risking either economic or societal instability. This became a reality in Venezuela, where collapsing oil revenues affected the government's spending capacity and ability to import essential goods, including food and medicine, which led to civil unrest and a humanitarian crisis.

For well-established export economies, such as Mexico and the Gulf States, economic diversification away from fossil fuels has become a priority – in the case of Saudi Arabia this has been as part of a comprehensive vision for a post-oil future.

For well-established export economies, such as Mexico and the Gulf States, economic diversification away from fossil fuels has become a priority – in the case of Saudi Arabia this has been as part of a comprehensive vision for a post-oil future. After decades of high oil revenue dependence and policies to promote energy-intensive industries in these countries, the often-overlooked challenges of creating effective energy policy and reducing consumption subsidies, while increasing the productivity of non-oil sectors, are now becoming priority policy areas.

Unsustainable spending often begins before any major discoveries, for example in São Tomé and Príncipe and Madagascar, where a 'resource curse without natural resources' emerged due to

[15] While in theory, fossil fuel resources may present an opportunity for broad-based economic development, a body of literature shows that this is more likely in the mining sector (rather than oil and gas) e.g. McMahon, G. and Moreira, S. (2014), *The Contribution of the Mining Sector to Socioeconomic and Human Development*, Extractive Industries for Development Series; No. 30, Washington, DC: World Bank, https://openknowledge.worldbank.org/handle/10986/18660 (accessed 30 May 2018).
[16] Friedrichs, J. and Inderwildi, O. R. (2013), 'The Carbon Curse: Are Fuel Rich Countries Doomed to High CO_2 Intensities?', *Energy Policy* Vol. 62, November 2013, pp. 1356–1365, https://doi.org/10.1016/j.enpol.2013.07.076 (accessed 30 May 2018); Lahn and Bradley (2016), *Left Stranded? Extractives-led Growth in a Carbon-Constrained World*; UNECA (2017), *Greening Africa's Industrialization – Economic Report on Africa*, UNECA: Addis Ababa, http://www.uneca.org/publications/economicreport-africa-2016 (accessed 30 May 2018).
[17] Note that they are not historically low, only low in relation to the period 2004 to 2014.

overspending in expectation of the 'resource boom'.[18] In Ghana and Mozambique, international borrowing against expected income from large-scale fossil fuel development became unsustainable when these projects were delayed, creating a 'pre-source curse'.[19] Most recently, in Papua New Guinea, LNG development has failed to deliver the economic boost that was anticipated.[20] The resulting debt and the international dependencies associated with it will shape politics and development choices in these countries for many years to come.[21]

Taken together, these trends suggest that the risks of dependence on fossil fuel sectors for income, energy security or industrial growth will only increase and evolve in nature over the coming decades.

Why focus on developing countries?

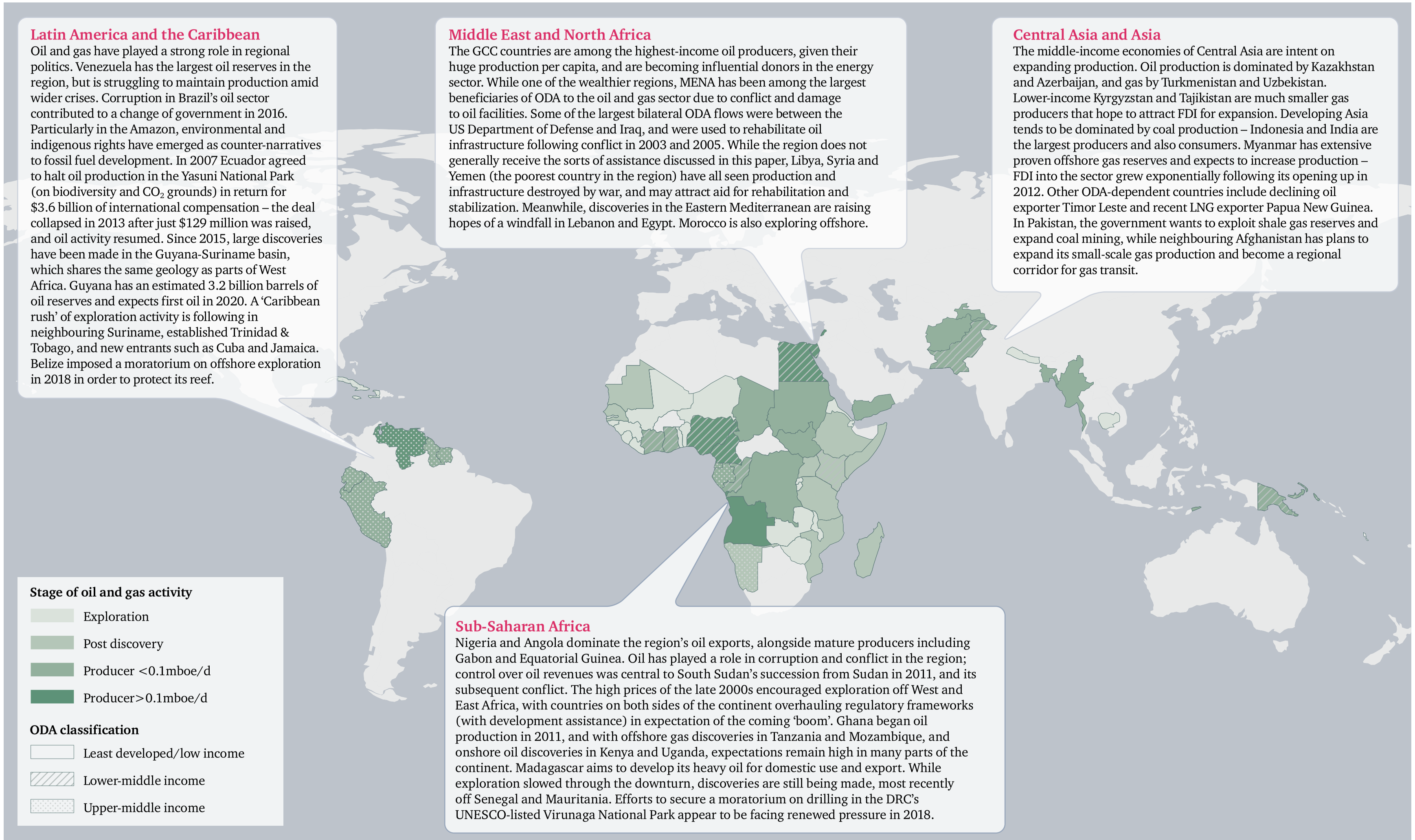
This paper is aimed at the governments of aid-dependent developing countries that are looking to explore for oil and gas, develop existing discoveries, or expand existing reserves for export and/or domestic use. For this purpose 'developing countries' are defined as least developed, low and lower-middle-income economies as defined by the OECD.[22] At least half of the 143 countries that fall under this definition, including 80 per cent of all least developed countries and low-income countries (LDCs/LICs) and one-quarter of all lower-middle-income countries (LMICs), are currently exploring for oil and gas, developing discoveries or have existing production (Figure 1). The strategic choices that the governments of these countries take will affect the lives of over 1.6 billion people.

Given that the majority of developing countries looking to further develop or expand their fossil fuel resources are in sub-Saharan Africa and Central America and the Caribbean, these regions are a natural focus for this paper. As set out above, countries in these regions were among the least prepared to manage the commodities price falls of recent years. Drawing on country case studies of Ghana and Tanzania, and discussions with many other low and lower-middle-income countries, this paper provides examples of how the issue of carbon risk might be approached, including through scenario analyses and multi-stakeholder dialogues on the role of the fossil fuel sector in national planning.

The country examples presented in chapters 3 and 4 are not intended to be representative of all developing countries. They are presented as useful comparisons, given their different stages of development and contrasting fossil fuel reserves and revenue prospects. The upper-middle-income, industrializing economies of developing Asia face different challenges, not least because the governance profiles of donors and recipients of development assistance, and the mechanisms and channels of support, are markedly different. The same is true for some of the upper-middle-income economies of Latin America, Eastern Europe and Central Asia. Nonetheless, the analysis presented in this paper should still be of broad relevance, and may help signpost areas in need of further research.

[18] Frynas, J. G., Wood, G. and Hinks, T. (2017), 'The Resource Curse without Natural Resources: Expectations of Resource Booms and their Impact', *African Affairs*, 116(463): pp. 233–260, https://doi.org/10.1093/afraf/adx001 (accessed 30 May 2018).
[19] Cust, J. and Mihalyi, D. (2017), *The Presource Curse,* IMF Finance and Development, http://www.imf.org/external/pubs/ft/fandd/2017/12/pdf/cust.pdf (accessed 30 May 2018).
[20] PNG's economy was expected to double with LNG production, but in fact grew just 10 per cent (mostly around the foreign-owned gas sector itself). Meanwhile household incomes fell by 6 per cent (despite predictions of an 84 per cent increase) and employment fell by 27 per cent (despite predictions of a 42 per cent increase). See Jubilee Australia (2018), *Double or Nothing: The Broken Economic Promises of PNG LNG,* April 2018, http://www.jubileeaustralia.org/latest-news/new-jubilee-report-shows-that-efic-funded-png-lng-project-has-hurt-png (accessed 31 May 2018).
[21] Lahn, G. and Stevens, P. (2017), *The Curse of the One-Size-Fits-All Fix: Re-evaluating what we know about extractives and economic development*, UNU-WIDER Working Paper, https://www.wider.unu.edu/publication/curse-one-size-fits-all-fix (accessed 30 May 2018).
[22] As defined by the OECD's DAC list of ODA recipients for 2018, 2019 and 2020, available at http://www.oecd.org/dac/financing-sustainable-development/development-finance-standards/daclist.htm (accessed 19 May 2018).

Figure 1: Oil and gas exploration and production in selected developing countries



Latin America and the Caribbean

Oil and gas have played a strong role in regional politics. Venezuela has the largest oil reserves in the region, but is struggling to maintain production amid wider crises. Corruption in Brazil's oil sector contributed to a change of government in 2016. Particularly in the Amazon, environmental and indigenous rights have emerged as counter-narratives to fossil fuel development. In 2007 Ecuador agreed to halt oil production in the Yasuni National Park (on biodiversity and CO_2 grounds) in return for $3.6 billion of international compensation – the deal collapsed in 2013 after just $129 million was raised, and oil activity resumed. Since 2015, large discoveries have been made in the Guyana-Suriname basin, which shares the same geology as parts of West Africa. Guyana has an estimated 3.2 billion barrels of oil reserves and expects first oil in 2020. A 'Caribbean rush' of exploration activity is following in neighbouring Suriname, established Trinidad & Tobago, and new entrants such as Cuba and Jamaica. Belize imposed a moratorium on offshore exploration in 2018 in order to protect its reef.

Middle East and North Africa

The GCC countries are among the highest-income oil producers, given their huge production per capita, and are becoming influential donors in the energy sector. While one of the wealthier regions, MENA has been among the largest beneficiaries of ODA to the oil and gas sector due to conflict and damage to oil facilities. Some of the largest bilateral ODA flows were between the US Department of Defense and Iraq, and were used to rehabilitate oil infrastructure following conflict in 2003 and 2005. While the region does not generally receive the sorts of assistance discussed in this paper, Libya, Syria and Yemen (the poorest country in the region) have all seen production and infrastructure destroyed by war, and may attract aid for rehabilitation and stabilization. Meanwhile, discoveries in the Eastern Mediterranean are raising hopes of a windfall in Lebanon and Egypt. Morocco is also exploring offshore.

Central Asia and Asia

The middle-income economies of Central Asia are intent on expanding production. Oil production is dominated by Kazakhstan and Azerbaijan, and gas by Turkmenistan and Uzbekistan. Lower-income Kyrgyzstan and Tajikistan are much smaller gas producers that hope to attract FDI for expansion. Developing Asia tends to be dominated by coal production – Indonesia and India are the largest producers and also consumers. Myanmar has extensive proven offshore gas reserves and expects to increase production – FDI into the sector grew exponentially following its opening up in 2012. Other ODA-dependent countries include declining oil exporter Timor Leste and recent LNG exporter Papua New Guinea. In Pakistan, the government wants to exploit shale gas reserves and expand coal mining, while neighbouring Afghanistan has plans to expand its small-scale gas production and become a regional corridor for gas transit.

Sub-Saharan Africa

Nigeria and Angola dominate the region's oil exports, alongside mature producers including Gabon and Equatorial Guinea. Oil has played a role in corruption and conflict in the region; control over oil revenues was central to South Sudan's succession from Sudan in 2011, and its subsequent conflict. The high prices of the late 2000s encouraged exploration off West and East Africa, with countries on both sides of the continent overhauling regulatory frameworks (with development assistance) in expectation of the coming 'boom'. Ghana began oil production in 2011, and with offshore gas discoveries in Tanzania and Mozambique, and onshore oil discoveries in Kenya and Uganda, expectations remain high in many parts of the continent. Madagascar aims to develop its heavy oil for domestic use and export. While exploration slowed through the downturn, discoveries are still being made, most recently off Senegal and Mauritania. Efforts to secure a moratorium on drilling in the DRC's UNESCO-listed Virunaga National Park appear to be facing renewed pressure in 2018.

Source: Compiled by authors, drawing on OECD-DAC (2018) country classifications; EIA production figures for oil (2017) and gas (2015); country and company reports.
Note: Includes LDCs and LICs with oil and gas activities, and selected LMIC and UMIC economies.

Why focus on MDBs and donor development agencies?

With MDBs and donor countries promising to increase climate finance and assist countries in their transition to a low-carbon development pathway, it is essential that they consider how their support for fossil fuel development affects these objectives. MDBs and donor governments have faced growing pressure from a range of civil society actors to demonstrate how their assistance to fossil fuel development abroad aligns with their international commitments to emissions mitigation.[23] Many MDBs and donors are now reforming their approaches to fossil fuel development to ensure their alignment with climate commitments (see Annex I for case studies on MDB and donor strategies).

This paper focuses primarily on MDBs and donor agencies, although it acknowledges the significant influence of non-ODA state institutions with an interest in overseas development (see Box 2). It also has relevance for other development actors, including NGOs, philanthropic foundations and for-profit consultancies, which often deliver ODA-funded programmes and projects.

Box 2: What do we mean by 'development assistance'?

Foreign aid works in many ways, not all of which are covered here. This paper defines 'development assistance' to the fossil fuel and energy sectors as development finance and programmes of technical, capacity and policy assistance that is delivered via the primary channels of ODA, e.g. bilaterally, via a donor country's development agency, and multilaterally, primarily through MDBs.

Bilateral development assistance is where aid is provided directly by a donor country to a recipient country. The bulk of this assistance is typically delivered by a state development agency such as the UK's Department for International Development (DFID) or the US Agency for International Development (USAID). The remainder may be spent by other departments – typically those related to foreign affairs, business and trade – or 'cross-government' funds. In 2016–17, for instance, 72.5 per cent of the UK's ODA was spent by DFID, 5.5 per cent by the Department for Business, Energy and Industrial Strategy (BEIS), 4 per cent by the Foreign & Commonwealth Office (FCO) and the remaining 18 per cent by other departments.[24] Donor countries have full control over where and how this assistance is delivered.

Multilateral assistance covers support from MDBs (or other multilateral development finance institutions) including the World Bank Group, the European Bank for Reconstruction and Development (EBRD), the Asian Development Bank (ABD) and the African Development Bank (AfDB). It also covers multi-stakeholder financial vehicles including the World Bank-administered Global Environment Facility (GEF) and the Climate Investment Funds (CIF). International organizations with a development mandate such as the United Nations Development Programme (UNEP) also offer assistance to the fossil fuel sectors. These institutions are owned by their respective stakeholder countries, which have voting rights and influence, if not full control over how assistance is delivered.

Development assistance delivered via these multilateral and bilateral channels tends to share similar objectives – namely alleviating poverty, and promoting sustainable and equitable economic development. While they are not the focus of this paper, other state institutions with a development remit tend to have wider objectives, often including an element of trade and investment promotion for the donor country. They include:

[23] For example: Mainhardt, H. (2017), *World Bank Development Policy Finance Props up Fossil Fuels and Exacerbates Climate Change: Findings from Peru, Indonesia, Egypt, and Mozambique*, Bank Information Center, p. 1, http://www.bankinformationcenter.org/wp-content/uploads/2017/01/Exec-Summary-1.11.17-2.pdf (accessed 30 May 2018); Inclusive Development International (2016), *Disaster for Us and the Planet: How the IFC is Quietly Funding a Coal Boom, Outsourcing Development: Lifting the Veil on the World Bank Group's Lending Through Financial Intermediaries,* https://www.inclusivedevelopment.net/wp-content/uploads/2016/09/Outsourcing-Development-Climate.pdf (accessed 30 May 2018); Han Chen et al. (2016), *Carbon Trap: How International Coal Finance Undermines the Paris Agreement*, Natural Resources Defense Council and Oil Change International, https://assets.nrdc.org/sites/default/files/carbon-trap-international-coal-finance-report.pdf?_ga=2.133822414.1793835675.1524843154-892593327.1524843154 (accessed 30 May 2018).

[24] DFID (2018), *Statistics on International Development: Provisional UK Aid Spend 2017*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/697331/Statistics-International-Development-Provisional-UK-aid-spend2017.pdf (accessed 30 May 2018).

- Development finance institutions (DFIs) or 'policy banks' – which often work alongside development agencies and MDBs with the dual objective of generating both a development impact and a financial return. Many have the explicit objective of leveraging private sector finance into developing economies. Some, such as the UK's Commonwealth Development Corporation (CDC), Norway's NORFUND and the US Overseas Private Investment Corporation (OPIC) are fully state owned, while others such as Dutch policy bank FMO, are joint public-private owned.[25]
- Export credit agencies (ECAs) – which have commercial remits and work to de-risk trade and investment in developing countries. Some ECAs fall under the same organization as the state's DFI, for example the KfW IPEX-Bank under Germany's KfW Group. These actors can have significant influence over the pathway that developing countries take, particularly where they provide finance or guarantees for upstream fossil fuel development and large-scale power projects.[26]

The activities of these actors may be coordinated with bilateral and multilateral ODA to a degree, but they are rarely completely aligned. Their governance structures and investment processes vary; some have their investment strategies set by the relevant ministry and have ministerial representation on their boards, while others operate more or less independently.[27] In some cases, such as where finance for coal-mining and coal-fired power is provided,[28] their support may be in direct conflict with emerging norms in ODA.

This paper focuses on the established MDBs and donors that are members of the Development Assistance Committee (DAC) of the Organisation for Economic Co-operation and Development (OECD).[29] However, it acknowledges the rapidly expanding role of emerging donors – including those of the BRICS and the GCC countries; and emerging development banks such as the Asian Infrastructure Investment Bank (AIIB). These institutions are at a much earlier stage of their operations and policy development, and may also find the paper's analysis and recommendations of interest.

Development assistance to the fossil fuel sector takes a number of forms, from finance and guarantees for upstream activities and (often linked) thermal power infrastructure, to programs of technical assistance, policy advice and institutional capacity-building. MDBs tend to play a greater role in financing upstream fossil fuels than development agencies, for whom technical and policy advice is often their sole or primary form of support to the sector. The six major multilateral development banks provided over $13 billion in financing and guarantees for fossil fuel-fired electricity generation and almost $9 billion for upstream oil and gas activities between 2010 and 2015.[30] OECD-DAC data suggests that bilateral ODA to the fossil fuel-fired power and the oil and gas sectors stood at almost $5.5 billion and $525 million over the same time frame.[31] Both are likely to be low estimates.[32]

[25] Dickinson, T. (ND), *Development Finance Institutions: Profitability Promoting Development*, www.oecd.org/dev/41302068.pdf (accessed 30 May 2018).
[26] OECD (ND), 'Export Credits', http://www.oecd.org/trade/exportcredits.htm (accessed 30 May 2018).
[27] ODI (2011), *Comparing Development Finance Institutions Literature Review,* London, Overseas Development Institute, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/67635/comparing-DFIs.pdf (accessed 30 May 2018).
[28] Public finance, primarily through the DFIs and ECAs of four G20 nations – China, Japan, Germany and South Korea – financed over 80 per cent of the $76 billion that G20 nations committed to coal projects between 2007–15. See Chen, H., Doukas A., Schmidt J., and Vollmer, S. L. (2016), *Carbon Trap: How International Coal Finance Undermines the Paris Agreement*, NRDC, https://www.nrdc.org/resources/carbon-trap-how-international-coal-finance-undermines-paris-agreement (accessed 30 Jun. 2018).
[29] This has 30 bilateral donor members, with several institutions including those mentioned above, holding 'observer status'. The DAC gathers data from over 210 multilateral organizations and funds, including those from a growing group of non-DAC donors and smaller multilateral trust funds. See ODI (2016), *Bilateral versus multilateral aid channels*, https://www.odi.org/sites/odi.org.uk/files/resource-documents/10393.pdf (accessed 30 May 2018); OECD (2013), *'What do we know about Multilateral Aid?'*, https://www.oecd.org/dac/aid-architecture/13_03_18%20Policy%20Briefing%20on%20Multilateral%20Aid.pdf (accessed 30 May 2018).
[30] Chatham House calculations based on data from Oil Change Shift the Subsidies Database (2016). Number includes all grants, loans, equity investments, guarantees and risk management mechanisms to fossil fuels supply and generation. Total MDB support to fossil fuels (including supply, generation, transport, transmission and distribution and other related activities) stood at $52 billion over the same period.
[31] Chatham House calculations based OECD-DAC data (2018). Number includes all commitments to coal, oil and gas-fired generation only (excluding distribution and transmission) in the period 2010–15. Estimates of bilateral ODA at sector level are limited by incomplete reporting (many MDBs and DFIs do not report at all) and overlap between institutions e.g. development agencies, DFIs, ECAs (as set out in Box 2).
[32] Estimates of bilateral ODA at sector level are limited by incomplete reporting (many MDBs and DFIs do not report at all) and overlap between institutions e.g. development agencies, DFIs, ECAs (as set out in Box 2).

These are small sums of investment when considered against total global investment in fossil fuel supply and generation, which stood at $706 billion in 2016 alone.[33] These are also small sums when considered against rapidly scaling MDB commitments to climate finance, which reached $32 billion in 2017 (of which 79 per cent was for climate mitigation).[34] Why then, with so much private capital available and with growing climate commitments, would MDBs and donors support upstream activities? There are several reasons.

First, in economic development terms, FDI and export revenues from the sector can offer a source of income (foreign exchange) for developing countries, for which there are few if any comparable alternatives. Fuel supplies also have the potential (with the right infrastructure) to improve domestic access to energy and support industrialization. Many MBDs and donors have promoted oil and gas development as a potentially 'transformative' economic opportunity and a 'chance to graduate from aid'. The role of natural gas as a 'bridging' fuel within a wider low-carbon development vision has also been of interest to development actors in recent years, particularly where it has the potential to displace coal-fired power or reliance on fuel oil.

In economic development terms, FDI and export revenues from the sector can offer a source of income (foreign exchange) for developing countries, for which there are few if any comparable alternatives.

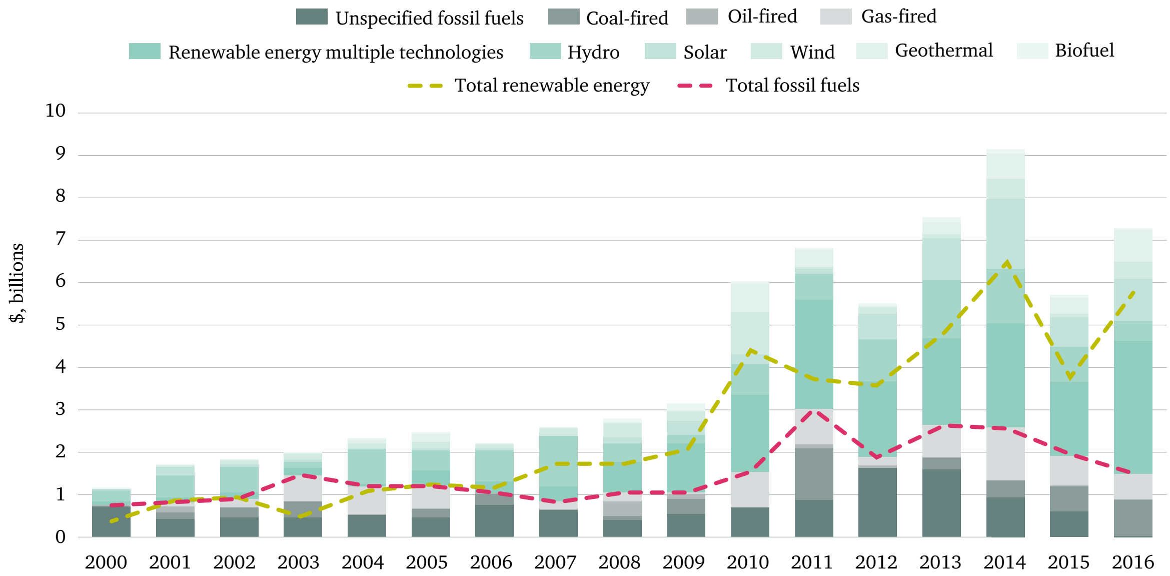
Second, support for 'good governance' and policy and institutional development can help avoid negative resource curse impacts. The focus of development assistance has evolved over the decades. Following the economic crises of the 1980s, development assistance emphasized attracting FDI through favourable investment terms. In the 1990s, it incorporated rising concerns about negative governance, economic and social outcomes associated with the resource curse. In the early 2000s, the emergence of 'good governance' regimes stressed transparency and greater accountability as the 'cure' for resource curse ills. Since the late 2000s, there has been a growing focus on cross-sector linkages and integration with the wider economy.[35] Climate considerations have not typically featured in this assistance, beyond sector-specific measures to eliminate flaring, enhance energy efficiency and increase RE use.

Third, support to the fossil fuel sector can lend considerable strategic influence. Long-standing relationships with country partners mean that MDBs and donor countries often influence fossil fuel investment frameworks, development decisions and models of growth through their policy and technical assistance. Development assistance is typically offered in response to country requests, and given that upstream development is often a political priority for governments, these requests may present an opportunity for increasing influence in a developing country. Particularly where fragile and conflict-affected states such as Iraq, Somalia and Afghanistan are concerned, assistance to the sector may be considered as a means of stabilization, particularly where it centres on good governance and transparency.[36]

[33] Investment in fossil fuels, including $709 billion in supply and $117 billion in thermal generation, and accounted for 57 per cent of a total $1.7 trillion investment in global energy systems (including supply, generation and distribution) in 2016. See International Energy Agency (2017), 'World Energy Investment 2017', https://www.iea.org/publications/wei2017/#section-1-6 (accessed 30 May 2018).
[34] Representing a 30 per cent increase year-on-year. *Joint Report on Multilateral Development Banks' Climate Finance* (2017), https://reliefweb.int/sites/reliefweb.int/files/resources/2017-joint-report-on-mdbs-climate-finance.pdf (accessed 11 Jul. 2018).
[35] In their analysis of the sector, Dietsche et al. usefully identify four phases of activity and thinking, Dietsche, E. et al. (2013), *Extractive industries, development and the role of donors*, Oxford Policy Management, p. 29, http://www.opml.co.uk/sites/default/files/OPM_DFID%20topic%20guide_web.pdf (accessed 30 May 2018).
[36] For example, US and Japanese ODA flows to Iraq in the mid-2000s are by far the largest bilateral ODA flows to the fossil fuel sector in recent years. Donors often note the value of development assistance to the extractive sector as an influential diplomatic channel where fragile and conflict-affected states, given the political priority it accords and the FDI it can support. The wider impact of FDI to the extractive sector on conflict dynamics is a different matter.

The rationale for assistance to the energy sector (including both fossil fuel and RE generation, as well as transmission and distribution) is more straightforward. MDBs and donors consider access to energy as crucial to supporting economic growth, and at the same time, the sector often fails to attract commercial investment. Notwithstanding the limitations of OECD-DAC data, there appears to be a clear and accelerating trend towards clean energy. Figure 2 shows how support for RE has outpaced support to thermal generation since 2006, and now accounts for 65 per cent of total energy ODA.

Figure 2: Reported ODA commitments to power generation, by technology, 2000–16



Source: CH calculations based on data from the Creditor Reporting System (CRS) Aid Activity Database, OECD.stat (2018).
Note: The chart shows all multilateral and DAC donor aid *commitments* in any given year. A commitment may be *disbursed* over several years. Investment guarantees, 'other official flows' e.g. from export credit agencies and non-DAC donor commitments, are not shown.

The real impact of MDB and donor engagement in these sectors is even greater than the sum of their investment. Where the policy and business environment is perceived to be high-risk and the cost of capital is prohibitively high, finance and guarantees provided by MDBs can effectively 'de-risk' investments and help mobilize and leverage much larger sums of private capital into the sector.[37] The OECD estimates that ODA – and particularly investment guarantees – helped raise $81.1 billion from the private sector between 2012 and 2015, including $20 billion in the energy sector and $5.2 billion in natural resources and mining.[38] Securing downstream investments in energy and industry are often critical to getting upstream investments agreed in the first place. The World Bank's largest ever guarantee of $700 million, for Ghana's gas-to-energy infrastructure, was intended to leverage a further $7.9 billion in private finance. It was key to the development of the Ghana's Sankofa gas field.[39]

[37] The World Bank estimates that for every $1 of MDB spending, an estimated $2–5 of private sector capital is mobilized. See http://pubdocs.worldbank.org/en/69291436554303071/dfi-idea-action-booklet.pdf.
[38] Investment guarantees underpinned 44 per cent of the capital identified in the OECD study, but almost all flows to LDCs. See https://www.oecd-ilibrary.org/docserver/8135abde-en.pdf?expires=1530739454&id=id&accname=guest&checksum=7073EBA357A3895EC506E6595310071F.
[39] World Bank (2015), 'World Bank Approves Largest Ever Guarantees for Ghana's Energy Transformation', Washington, DC: World Bank, 30 July, http://www.worldbank.org/en/news/press-release/2015/07/30/world-bank-approves-largest-ever-guarantees-for-ghanas-energytransformation (accessed 30 May 2018).

2. Decarbonization and Global Fossil Fuel Markets

Following the Paris Agreement, the issue of carbon risk has risen rapidly up the international agenda. The trajectory implied by a 2°C carbon budget has significant implications for financial stability and the value of assets and investments over time – particularly fossil fuels. In response to this, public and private sector stakeholders in advanced economies are now re-evaluating their long-term strategies against a 2°C scenario, as well as nearer-term policy signals and demand-side shifts.

It is important that developing countries that are banking on securing foreign direct investment (FDI) into their fossil fuel sectors have a good understanding of the ways in which different actors are responding to evolving uncertainties and risks, and how this is re-shaping global investment patterns. This chapter uses UCL modelling (see Annex II for a full methodology) to show what a least-cost pathway for achieving a 'well below 2°C target' implies for oil, coal and gas markets. It also draws on dialogues held with MDBs, donors and the wider investment and finance communities, in order to explore real world thinking, trends and factors that will influence markets. The last section focuses on investment, both in terms of institutional investors, many of which are IOC shareholders, and other commercial financiers that will influence capital available for infrastructure and energy systems.

The implications of the global carbon budget

The international commitment to limit global warming to well below 2°C above pre-industrial levels – and as close as possible to 1.5°C – means that fossil fuel use must fall dramatically over the next 30 years. This limit on temperature increases can be translated into a 'carbon budget', or the amount of carbon dioxide (CO_2) that can be emitted through the burning of fossil fuels by 2100 (and beyond) before the average global temperature rise exceeds 2°C.[40] This equates to a total carbon budget of around 830 gigatonnes of carbon dioxide ($GtCO_2$) from 2017, which will be used up in 20 years under current emissions trajectories.[41] Previous research estimated that under such a 2°C carbon budget, 80 per cent of coal, 50 per cent of oil and 33 per cent of gas reserves would be 'unburnable'.[42]

The 1.5°C limit translates into a much smaller carbon budget of around 240 $GtCO_2$, which at current rates would be used in just four years, and would in turn imply that a higher percentage of fossil fuel reserves are 'unburnable'.

Moreover, the ambition expressed under the Paris Agreement is to aim for a 1.5°C limit, given the severity of climate impacts implied by even the 2°C rise. This translates into a much smaller carbon budget of around 240 $GtCO_2$, which at current rates would be used in just four years (see Annex II), and would in turn imply that a higher percentage of fossil fuel reserves are 'unburnable'.

[40] Based on a 66 per cent probability of achieving this 2°C limit. See Annex II for a full methodology of the global modelling.
[41] See Rogelj, J., Schaeffer, M., Friedlingstein, P., Gillett, N. P., van Vuuren, D. P., Riahi, K., Allen, M. and Knutti, R. (2016), 'Differences Between Carbon Budget Estimates Unravelled', *Nature Climate Change,* 6: pp. 245–252, http://dx.doi.org/10.1038/nclimate2868 (accessed 30 May 2018).
[42] McGlade and Ekins (2015), 'The geographical distribution of fossil fuels unused when limiting global warming to 2°C.'

Competition between different fossil fuels for their 'share' of the remaining carbon budget is likely to intensify in the coming years. Coal is the most carbon intensive fuel in the global energy mix, and all 2°C scenarios show a sharp reduction in its use within the next five years. A greater range of trajectories exists for oil and gas use, depending on the assumptions made regarding transition pathways and the availability and affordability of clean technologies.[43]

Uncertainties within decarbonization scenarios

There are three broad areas of uncertainty that are subject to policy influence: the level of climate ambition and the speed of response; the role of carbon capture and storage (CCS), bioenergy[44] with CCS (BECCS) and other negative emissions technologies (NETs); and 'demand side' drivers, including the speed at which new energy technologies and business models emerge and investment patterns shift.[45]

As a result of the varying assumptions that mainstream models make regarding these uncertainties, there are a range of possible pathways to a 'well below 2°C' world. This chapter explores the key assumptions and uncertainties inherent in the modelling undertaken for this paper, which shows pathways under five credible climate scenarios (see Table 1). These scenarios are based on the latest available data (2016), and explore the most cost-effective pathways to a given level of climate ambition, rather than reflecting what is happening, or what is most likely to happen. A full methodology is provided in Annex II.

Table 1: Climate mitigation scenarios in TIAM-UCL

Scenario	Assumption
NDC	Reflects current country pledges (NDCs) under the UNFCCC process, resulting in around 3.5°C rise in global temperatures.
2D	Represents a 2°C limit based on a central carbon budget of 910 $GtCO_2$ (between 2015–2100), or 830 $GtCO_2$ (taking into account the last two years of emissions).
2D590	Represents a 2°C limit based on a more stringent budget of 590 $GtCO_2$ as a result of lower than anticipated action on non-CO_2 GHGs.
No CCS	Represents a 2°C limit as under 2D but with no CCS deployment.
Tech acceleration	Reflects stronger cost reductions for solar PV, wind and electric vehicles (EVs), with vehicle cost parity in the mid-2020s compared to 2030s under 2D.

Source: Compiled by authors.

[43] Peters, G. (2017), 'Does the carbon budget mean the end of fossil fuels?', Center for International Climate Research, http://www.cicero.uio.no/en/posts/klima/does-the-carbon-budget-mean-the-end-of-fossil-fuels (accessed 30 May 2018).
[44] Bioenergy refers to energy generated by the combustion of biomass, or renewable biological materials e.g. wood and agricultural crops and organic waste. Bioenergy is used as a 'catch all' term where global trends are discussed, but where country-level considerations are covered, it is important to draw the distinction between 'traditional' forms of bioenergy e.g. firewood and charcoal burning, which are associated with significant negative public health and environmental impacts, and modern bioenergy solutions, like industrial waste to power and heat technologies and second-generation biofuels in the road transport and aviation sectors.
[45] There are also significant uncertainties relating to climate system response, e.g. climate sensitivity, which are beyond the scope of this paper. There is also a debate on the impact of climate sensitivity on the size of budget, with different papers implying higher or lower budgets from the range in the IPCC 5th Assessment Report. A useful overview can be found here Peters, G. (2018), 'Making the Carbon Budget Bigger', Cicero, https://www.cicero.uio.no/no/posts/klima/making-the-carbon-budget-bigger (accessed 30 May 2018). A paper by Millar et al. also makes the case for a larger carbon budget, based on different assumptions about observed warming Millar, R. J. et al. (2017), 'Emission budgets and pathways consistent with limiting warming to 1.5 C', *Nature Geoscience*, 10(10), 741. https://www.nature.com/articles/ngeo3031 (accessed 30 May 2018).

Level of climate ambition, and speed of response

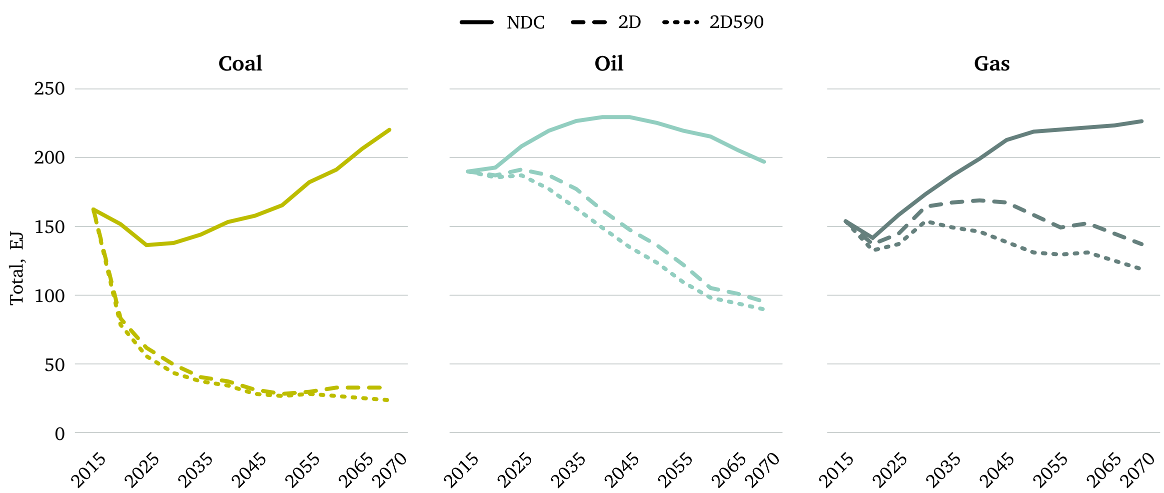
Figure 3 illustrates the difference between the climate commitments that countries have set out in their current NDCs, and the level of ambition required to stay within a 2°C carbon budget. There is much lower use across *all* fossil fuels in a 2°C budget, compared to a current NDC (equivalent to a 3.5°C temperature rise) budget. While oil and gas remain an important part of the global energy system within a 2°C carbon budget, oil production falls to around half of current levels shortly after 2050, and there is little growth in gas, which remains at similar production levels as today.

These, like most mainstream scenarios, assume a rapid reduction in coal use; a pathway that is most cost-effective, but may be challenging to realize politically. While coal use slowed in 2016, it is not yet on the 2D pathway shown in Figure 3. Higher-than-expected coal use in the near future would imply the need for further reductions in oil and gas use by 2050, constraining their potential role within a 2°C carbon budget.

The scenarios also assume rapid action. If action is delayed and near-term emissions remain at high levels there would need to be much sharper subsequent reductions in CO_2 emissions. This would also likely reduce future 'space' for fossil fuel use, as well as incurring much greater systems costs, as more energy, transport and other infrastructure is 'stranded'.

A further uncertainty in the size of the carbon budget relates to overall climate ambition and efforts to reduce non-CO_2 greenhouse gases (GHGs), which account for almost one-third of global emissions.[46] Their primary sources include fugitive emissions from the energy sector, industrial processes and agriculture. Within the 2°C budget, an aggressive non-CO_2 GHG reduction scenario could imply a larger available carbon budget of 1,160 $GtCO_2$, while weak efforts to mitigate non-CO_2 GHGs could result in a smaller available carbon budget of 590 $GtCO_2$.[47] This is shown by the 2D590 scenario in Figure 3, and has particular implications for the role of natural gas.

Figure 3: Global fossil fuel production under NDC, 2D and 2D590 scenarios, 2015–70



Source: UCL analysis with TIAM-UCL, 2017.

[46] Non CO_2 GHGs include methane, nitrous oxide, and fluorinated greenhouse gases.
[47] Rogelj et al. (2016), 'Differences Between Carbon Budget Estimates Unravelled'.

In recent years, natural gas has been promoted by development actors as an alternative to coal and as a 'bridge' to a low-carbon future. Many IOCs have pivoted towards gas as part of their efforts to adapt to a decarbonizing world. The discovery of new information regarding non-CO_2 emissions may also have implications for the role of gas within the global carbon budget. Due to its high global warming effects, methane (CH_4) emissions from gas production, transport and use have the potential to undermine the benefits of gas over other fossil fuels, in terms of its carbon intensity.[48] The risks of methane leakage typically remain underexplored and poorly addressed at both the global and country levels.

The role of CCS, BECCS and other NETs

Most mainstream scenarios – including those produced by the IEA and major oil companies – assume a significant role for CCS and BECCS.[49] The deployment of CCS could allow the continued use of some fossil fuels for power generation and in heavy industry, where substitution is more challenging.[50] The use of BECCS would help offset remaining fossil fuel-based emissions via negative emissions, generated by a net transfer of CO_2 from the atmosphere, through the biosphere and into geological layers. In all but the most rapid and deep decarbonization scenarios, global emissions effectively overshoot the 2°C carbon budget by mid-century – many 2°C integrated assessment models (IAMs) assume net-negative emissions by 2070, with BECCS compensating for this earlier overshoot.[51]

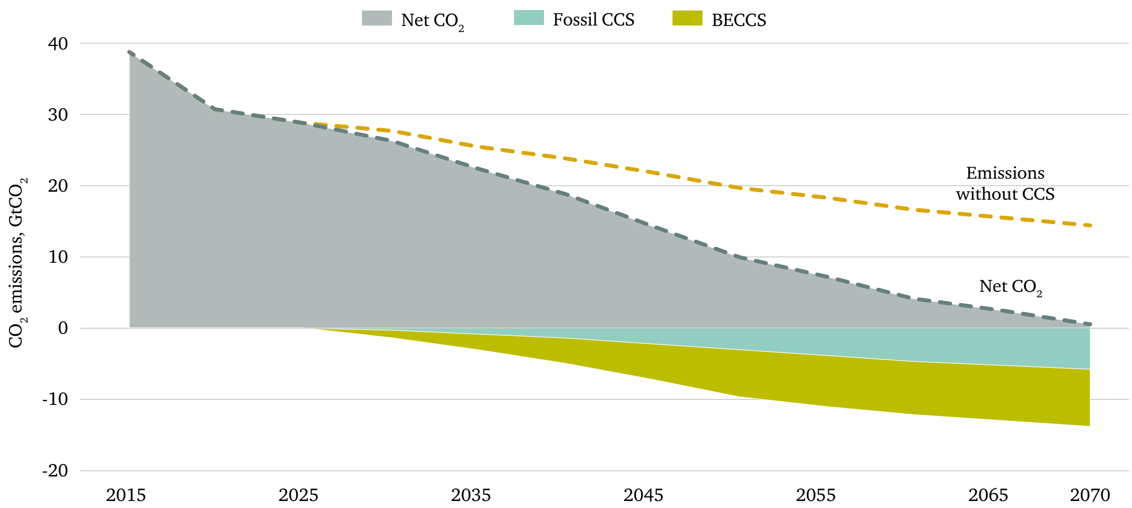
The global supply and emissions trajectories in Figure 4 are also premised on the availability of CCS and BECCS. Figure 4 illustrates the roles that CCS and BECCS play in the 2D scenario in this paper; in order for net CO_2 emissions to reach zero in 2070, CCS must deal with around 15 $GtCO_2$ (shown by the blue and green shaded areas). The cumulative CO_2 emissions that CCS would need to capture to 2100 are equivalent to the entire 2°C carbon budget – so the use of CCS effectively doubles the available carbon budget in this instance. The scaling of CCS and the bioenergy resource levels required for BECCS (along with the assumption that this resource is sustainable) therefore represent critical uncertainties for the available carbon budget and in turn, for future fossil fuel use.

The risks of CCS and BECCS not materializing – namely locking energy systems into a high emissions pathway – are not generally factored into mainstream scenario analyses, or made explicit to the policy community, nor are the sizable downside risks of deploying BECCS at the scale modelled.[52] At present, few countries are currently planning for CCS or BECCS, or mention them in their NDCs.[53] The 22 large-scale CCS projects currently in operation are clustered in North America, Northern Europe and China, and have typically emerged where they represented a small, incremental investment on an existing process, or where the resulting CO_2 has commercial value.[54] From an investor perspective,

[48] The most comprehensive review suggests a wide range of estimates for CH_4 leakage within the 0–10 per cent range, suggesting that methane leakage is a project-specific issue. See Balcombe, P., Anderson, K., Speirs, J., Brandon, N. and Hawkes, A. (2016), 'The Natural Gas Supply Chain: the Importance of Methane and Carbon Dioxide Emissions', *ACS Sustainable Chemistry & Engineering*, 5(1): pp. 3–20, http://dx.doi.org/10.1021/acssuschemeng.6b00144 (accessed 30 May 2018).
[49] Fuss, S., Canadell, J. G., Peters, G. P., Tavoni, M., Andrew, R. M., Ciais, P., Jackson, R. B., Jones, C., Kraxner, F., Nakicenovic, N., Le Quéré, C., Raupach, M. R., Sharifi, A., Smith, P. and Yamagata, Y. (2014), 'Betting on Negative Emissions', *Nature Climate Change*, 4(10): pp. 850–853, http://dx.doi.org/10.1038/nclimate2392 (accessed 30 May 2018).
[50] Industrial demand is perceived as hard to address, most of the residual coal use in the modelling in 2050, for instance, is metallurgical coal, which is currently very difficult to substitute in industrial processes such steel production.
[51] Obersteiner, M. et al. (2018), 'How to spend a dwindling greenhouse gas budget', *Nature Climate Change* Volume 8, pp. 7–10, http://www.nature.com/articles/s41558-017-0045-1 (accessed 21 Jun. 2018).
[52] Anderson, K. and Peters, G. (2016), 'The Trouble with Negative Emissions', *Science*, 354(6309): pp. 182–183, http://dx.doi.org/10.1126/science.aah4567 (accessed 30 May 2018).
[53] Peters, G. P. and Geden, O. (2017), 'Catalysing a Political Shift From Low to Negative Carbon', *Nature Climate Change*, 7: pp. 619–621, http://dx.doi.org/10.1038/nclimate3369 (accessed 30 May 2018).
[54] There are just 22 large-scale CCS projects in operation, which capture a combined 37 million tonnes per annum (Mtpa) of CO_2 emissions. See the Global CCS Institute, (2018), Projects Database, https://www.globalccsinstitute.com/projects, (accessed 30 May 2018).

CCS is not on the horizon; few commercial opportunities have arisen, and CCS does not typically feature in 'green finance' discussions.[55] Meanwhile, depending on the energy crop used and the efficiency of production, the level of BECCS deployment in many 2°C scenarios could require between half to five times the land area used to grow the world's entire current cereal harvest.[56]

Figure 4: Net CO_2 emissions under 2D scenario, 2015–70

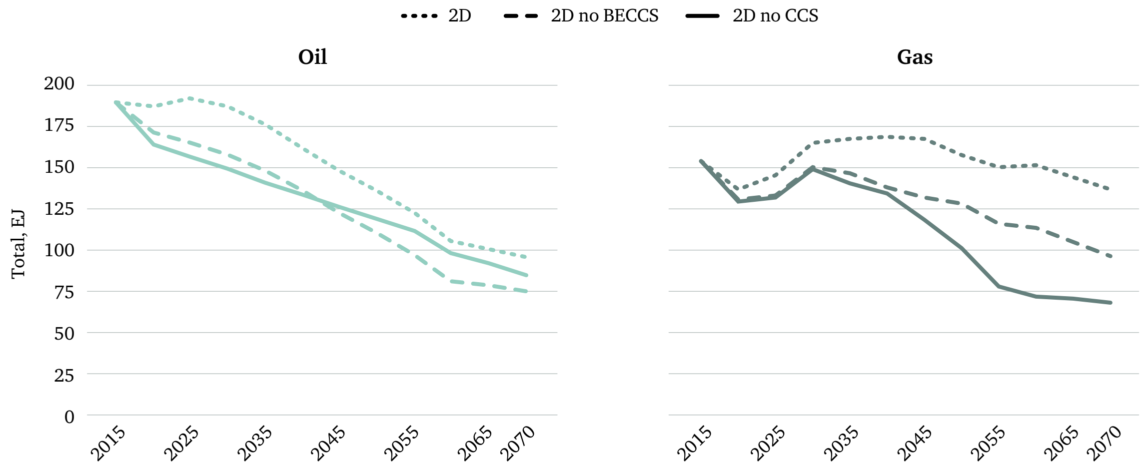


Source: UCL analysis with TIAM-UCL, 2017.

Without these technologies, the future role of fossil fuels will be strongly curtailed. A 'no CCS' scenario, which represents the current outlook, would have the greatest impact on gas. Compared to the standard 2°C scenario (with CCS), the production outlook is about 50 per cent lower in 2070 (Figure 5). Oil is considerably less sensitive to CCS; reflecting the fact that oil is considered the hardest of the fossil fuels to displace, given its central role in the transport sector. For growth areas of demand such as freight, shipping and aviation, there are few viable substitute clean energy technologies at present. The increased cost of mitigation without options such as CCS and BECCs – due to the greater production and use of advanced biofuels, hydrogen from electrolysis, and higher-cost RE it would imply – also presents a major challenge.[57]

[55] Based on comments from investors and financiers at the project's September 2017 workshop held at Chatham House.
[56] Fajardy, M. and Mac Dowell, N. (2017), 'Can BECCS deliver sustainable and resource efficient negative emissions?', *Energy and Environmental Science*, Vol. 10, pp. 1389–1426, http://pubs.rsc.org/en/content/articlelanding/2017/ee/c7ee00465f#!divAbstract, (accessed 15 Jun. 2018).
[57] Hughes, N. et al. (2017), *The Role of CCS in Meeting Climate Policy Targets*, London: Global CCS Institute, University College London, http://hub.globalccsinstitute.com/sites/default/files/publications/201833/report-role-ccs-meeting-climate.pdf (accessed 30 May 2018).

Figure 5: Oil and gas production levels under 2D scenarios with and without BECCS and CCS, 2015–70



Source: UCL analysis with TIAM-UCL, 2017.

Moreover, even without CCS or BECCS, other NETs – including afforestation, reforestation and biochar – would still be required for these reduced levels of fossil fuels to be sustainable. To meet the long-term objective of the Paris Agreement, CO_2 emissions would need to total around 830 $GtCO_2$ between 2017 and 2100; yet under the 'no CCS' scenario, cumulative CO_2 emissions would already be around 1,000 $GtCO_2$ in 2070, requiring other NETs to reduce this total. Once again, without NETs, the scenarios show an overly optimistic outlook for fossil fuel production.

Box 3: The difficulties of modelling 1.5°C

A 1.5°C scenario was not included in the modelling undertaken for this paper by UCL. Based on IPCC estimates, in order to limit temperature increases to 1.5°C above pre-industrial levels, the carbon budget would be approximately 240 $GtCO_2$, from 2015 onwards. This is significantly lower, and even more ambitious than the low and mid points of a 2°C budget range of 590 $GtCO_2$ and 830 $GtCO_2$ (estimated with a 66 per cent probability of achieving the target).

As shown in the paper by Hughes et al. (2017), even with optimistic options for CCS and BECCS, the TIAM-UCL model was not able to provide a feasible solution for a 1.5°C carbon budget.[58] The main reasons for this limit to increased ambition (compared to the already challenging 2°C case) include the limited NETs options considered (BECCS only), and a cap on global bioenergy resources of 130 exajoules (EJ) per year after 2050, which in turn constrains the negative emissions available to the system via BECCS.

By contrast, IAMs clearly are able to run 1.5°C scenarios.[59] However, they typically assume significantly higher contributions of negative emissions and bioenergy use than those assumed in the TIAM-UCL modelling.[60] Bioenergy use for a 1.5°C scenario (in the equivalent growth scenario used in TIAM-UCL), increases to over 200 EJ per year while cumulative levels of CO_2 captured are also more than 50 per cent higher than those observed in the TIAM-UCL modelling.[61]

[58] Ibid.
[59] Rogelj, J., Luderer, G., Pietzcker, R. C., Kriegler, E., Schaeffer, M., Krey, V., and Riahi, K. (2015), 'Energy system transformations for limiting end-of-century warming to below 1.5 C', *Nature Climate Change*, 5(6), 519.# https://www.nature.com/articles/nclimate2572 (accessed 30 May 2018).
[60] One exception is Van Vuuren et al. (2018), which uses an IAM to get to 1.5°C with constrained NETs use through aggressive mitigation actions. See Van Vuuren et al. (2018), 'Alternative pathways to the 1.5°C target reduce the need for negative emission technologies', *Nature Climate Change*, Volume 8, pp. 391–397, http://dx.doi.org/10.1038/s41558-018-0119-8 (accessed 21 Jun. 2018).
[61] Rogelj, J., Popp, A., Calvin, K. V., Luderer, G., Emmerling, J., Gernaat, D., Fujimori, S., Strefler, J., Hasegawa, T., Marangoni, G., Krey, V., Kriegler, E., Riahi, K., van Vuuren, D. P., Doelman, J., Drouet, L., Edmonds, J., Fricko, O., Harmsen, M., Havlík, P., Humpenöder, F., Stehfest, E., Tavoni, M. (2018), 'Scenarios towards limiting global mean temperature increase below 1.5°C', *Nature Climate Change,* doi:10.1038/s41558-018-0091-3, https://www.nature.com/articles/s41558-018-0091-3 (accessed 30 May 2018).

A number of scientists have noted the danger in increasing reliance on the large-scale deployment of new technologies and resources for mitigation,[62] and have suggested that this is a high risk strategy.[63] For these reasons, the modelling in this paper has not sought to further relax model assumptions in order to meet the target, as the deployment of such technologies under the 2°C carbon budget is already highly ambitious and requires an unprecedented rate of change. The forthcoming IPCC Special Report on 1.5°C will shed further light on mitigation pathways compatible with the 1.5°C target in the context of sustainable development pathways.

Disruptive shifts on the demand side

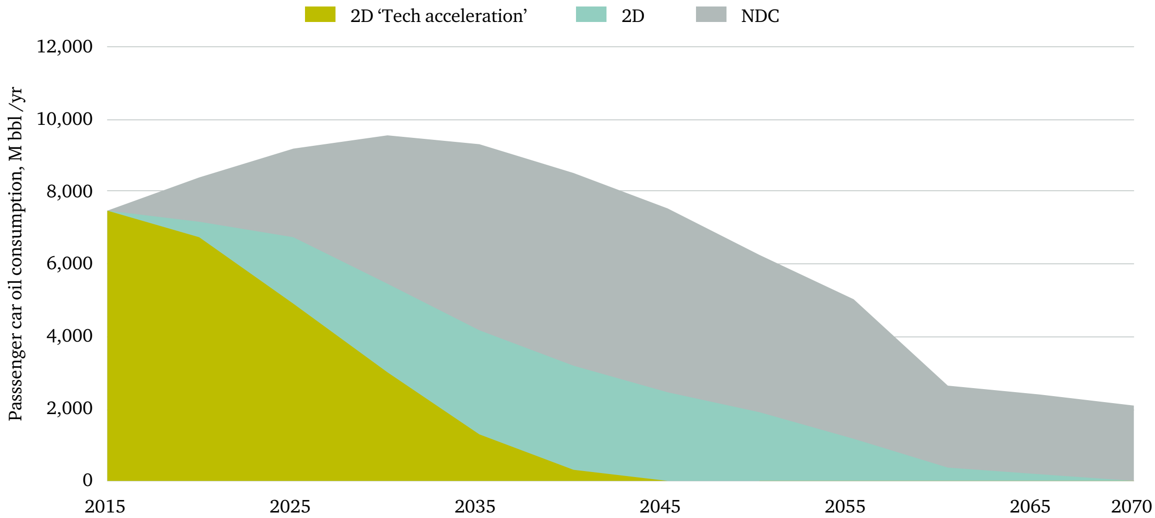
While 2°C scenarios provide a clear indication of the long-term direction that policy and public finance should take, demand will ultimately be influenced by a combination of government policies, fuel and fuel-substitute prices, technological advances, and new information and investment trends. Lines will not follow a smooth curve. For mainstream scenarios, anticipating non-linear drivers of demand – including disruptive shifts in technologies and behavioural shifts among consumers – has proved challenging. In recent years, the providers of these scenarios have repeatedly underestimated RE uptake and overestimated fossil fuel demand.[64] A similar picture is now emerging around projections of battery storage capacity and electric vehicle uptake.

> Providers of mainstream scenarios have repeatedly underestimated RE uptake and overestimated fossil fuel demand. A similar picture is now emerging around projections of battery storage capacity and electric vehicle uptake.

Expectations for future oil demand provide perhaps the best example of this uncertainty. The global scenarios developed for this project show relatively limited impact on oil production to 2030, compared to the reductions seen in the models for gas and coal. This is in part due to the 'head room' created by declining coal use and increasing CCS deployment, but it is also a result of transport being a more costly sector in which to effect change. It is assumed that electrification beyond light-duty road vehicles will be limited for the foreseeable future, given the difficulty of electrifying other sub-sectors such as freight and aviation. At the same time, the prospects for the displacement of oil by biofuels are also limited due to bioenergy resource constraints.

[62] Fuss, S., Canadell, J. G., Peters, G. P., Tavoni, M., Andrew, R. M., Ciais, P., and Le Quéré, C. (2014), 'Betting on negative emissions', *Nature Climate Change*, 4(10), 850, https://www.nature.com/articles/nclimate2392 (accessed 30 May 2018); EASAC (2018), *Negative emission technologies: What role in meeting Paris Agreement targets?*, Policy Report 35, European Academies' Science Advisory Council, https://easac.eu/fileadmin/PDF_s/reports_statements/Negative_Carbon/EASAC_Report_on_Negative_Emission_Technologies.pdf (accessed 30 May 2018).
[63] Anderson, K. and Peters, G. (2016), 'The Trouble with Negative Emissions', *Science*, 354(6309): pp. 182–183, http://dx.doi.org/10.1126/science.aah4567 (accessed 30 May 2018).
[64] See, for example, Muttitt, G. (2017), *Forecasting Failure*, Oilchange International and Greenpeace, https://www.greenpeace.org.uk/wp-content/uploads/2017/06/ForecastingFailureMarch2017.pdf (accessed 30 may 2018); Carbon Tracker (2017), 'Expect the Unexpected: The Disruptive Power of Low-carbon Technology', https://www.carbontracker.org/reports/expect-the-unexpected-the-disruptive-power-of-low-carbon-technology/ (accessed 30 May 2018); Muttitt, G. (2018), *Off-track – How the International Energy Agency Guides Energy Decisions Towards Fossil Fuel Dependence and Climate Change*, Oil Change International and the Institute for Energy Economic and Financial Analysis (IEEFA), April, http://priceofoil.org/content/uploads/2018/04/OFF-TRACK-the-IEA-Climate-Change.pdf (accessed 30 May 2018).

Figure 6: Oil consumption in the passenger car sector under NDC, 2D and 'tech acceleration' scenarios, 2015–70



Source: UCL analysis with TIAM-UCL, 2017.

As Figure 6 shows, more ambitious electrification rates in the passenger car sub-sector could have a significant impact on oil demand in the longer term. Under the NDC and 2D scenarios, it is assumed that EVs reach price parity with internal combustion engine (ICE) vehicles in the 2030s, and account for 6 per cent and 22 per cent of the global fleet in 2040. Under the 'tech acceleration' scenario it is assumed that price parity is reached in the mid-2020s and that EVs account for 75 per cent of the global fleet by 2040. Under such a scenario, oil use in the passenger car sub-sector would collapse by the 2040s (rather than the 2060s), and cumulative oil consumption in the sub-sector would reduce by over one-third to 2040.

Many factors will ultimately affect future oil demand in the transport sector, including efficiency improvements in ICE vehicles and reductions in the size of the global car fleet (due to urbanizing populations and the growth of business models such as ride sharing, which negate the need for car ownership), as well as the speed of EV uptake. Policies in major fuel consumer markets, driven by pressure for clean air are preparing to phase out the ICE. Governments in the EU and China have announced dates by which the sale of ICE vehicles will be outlawed. In shipping, a growth area for demand, an international agreement under the International Maritime Organization has set the goal of halving emissions from this sector by 2050.

While the 'tech acceleration' scenario is far more ambitious than even the most optimistic current forecasts for EV uptake,[65] it illustrates the impact that a more disruptive shift in the sector could have on demand, even when limited to the passenger vehicle sub-sector.

[65] Bloomberg New Energy has presented the most optimistic forecasts regarding both EV uptake and the decline in the absolute size of the global fleet in recent years. Their EV outlook sees EVs reaching price parity with ICE vehicles in 2030, and accounting for 35 per cent of the global fleet (530 million of a total 1.6 billion cars) in 2040. While this falls someway short of our 'tech acceleration' scenario, it is worth noting that BNEF's EV Outlook has been consistently revised up year by year. See https://about.bnef.com/blog/bps-energy-outlook-and-the-rising-consensus-on-ev-adoption/ (accessed 15 Jun. 2018).

Investor and financial market responses

Scenarios based on what 'should' happen to reach the internationally agreed emissions targets appear highly theoretical for country governments, investors and others wishing to know what is *likely* to happen on the demand side. However, the implications of climate mitigation goals are informing policies, regulation and consumer and shareholder preferences, so even from a purely commercial perspective, there is growing interest from a wide range of large investors and financiers regarding how to interpret these trends in a way that can inform the deployment of capital. There are two issues here:

- First, how the carbon-intensity of assets will affect their value over time, and, in turn, the profitability and fiscal stability of the companies, sectors and economies that are most exposed to them.
- Second, the extent to which decarbonization presents an opportunity for investment in clean energy, sustainable infrastructure and other areas of the low-carbon economy.

The varying time horizons of different market actors have presented one of the greatest barriers to effective coordination around both issues. In his landmark speech in 2015, Governor of the Bank of England Mark Carney described climate-related financial risks as a 'tragedy of the horizons'; with those engaged in monetary policy and sovereign ratings looking 2–3 years ahead, those concerned with fiscal policy looking up to a decade ahead, but few considering impacts beyond this.[66] Long-term investors, including institutional investors, pension funds, and sovereign wealth funds (SWFs), which face the dual challenge of ensuring short-term (3–5 years) and long-term (30–40 years) returns are perhaps the exception.

> Traditionally, the varying time horizons of different market actors have presented one of the greatest barriers to effective coordination around both carbon risk and direct climate impacts.

Long-term investors have been among the most active in managing their exposure to carbon risks. Some are using their shareholder voting rights to influence IOC behaviour; the New York State Common Retirement Fund and the Church of England, for example, successfully passed a shareholder resolution in 2017 with the support of 30 major institutional investors, compelling Exxon Mobil to report climate-related risks to its business.[67] Others have committed to divestment as part of a wider diversification strategy. Norges Bank, which manages Norway's $1 trillion SWF, stated in late 2017 that the 'government's wealth can be made less vulnerable to a permanent drop in oil prices' by divesting of its $35 billion of oil and gas stocks.[68] In early 2018, Mayor of New York Bill De Blasio announced that the city's pension fund would divest its $5 billion of fossil fuel company shares

[66] Bank of England (2015), 'Breaking the Tragedy of the Horizon – climate change and financial stability', Speech given by Mark Carney, governor of the Bank of England and chair of the Financial Stability Board, at Lloyd's of London, 29 September 2015, https://www.bankofengland.co.uk/-/media/boe/files/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability.pdf?la=en&hash=7C67E785651862457D99511147C7424FF5EA0C1A (accessed 30 May 2018).
[67] The percentage of shareholders supporting the proposal increased from 38 per cent in 2016 to 62 per cent in 2017. See Crooks, E. (2017), 'ExxonMobil bows to shareholder pressure on climate reporting', *Financial Times*, 12 December 2017, https://www.ft.com/content/8bd1f73a-dedf-11e7-a8a4-0a1e63a52f9c (accessed 30 May 2018).
[68] Norges Bank (2017), 'Norges Bank Recommends the Removal of Oil Stocks from the Benchmark Index of the Government Pension Fund Global (GPFG)', 16 November 2017, https://www.nbim.no/en/transparency/news-list/2017/norges-bank-recommends-the-removal-of-oil-stocks-from-the-benchmark-index-of-the-government-pension-fund-global-gpfg/ (accessed 30 May 2018).

(as well as launching a lawsuit against five IOCs for climate damages).[69] This movement is prompting major IOCs to pre-emptively adjust their strategies to demonstrate a less carbon-intensive portfolio, which will in turn influence how they choose to invest their capital.

Clear signalling at the international level has helped build consensus and improve alignment among these market actors. In 2015, the G20 asked the Financial Stability Board (FSB) to establish the Task Force on Climate-related Financial Disclosures (TCFD), in order to better understand the materiality of market risks (e.g. devalued or stranded assets) and physical risks (e.g. rising sea-levels, extreme weather events).[70] The TCFD's final report in July 2017 provided guidance on scenario analysis and a framework for the disclosure of climate risk and technical advice. At the One Planet Summit in Paris, in December 2017, FSB Chair Mark Carney and TCFD Chair Mike Bloomberg announced that 237 companies with a market capitalization of over $6.3 trillion, including 150 financial firms with over $81.7 trillion assets under management, had committed to TCFD implementation.[71]

As set out above, there are significant uncertainties regarding the speed of transition and the likely pathway in terms of technologies and energy mix over time. There is little in the way of a common baseline for analysis.

These companies and investors are looking to both 'top-down' policy signals – including what is required at the global level over the long term, and what countries have pledged in their NDCs in the shorter term – and 'bottom-up' trends including shifting demand patterns and disruptive new technologies. Commercial and asset allocation strategies reflect an actor's time frame and risk threshold; some may still invest in high-carbon areas, provided that assets can be quickly divested (or written-off) and capital re-allocated.[72] There is scope here for knowledge-sharing in terms of the creation and use of carbon pricing, and the development of investment strategies that take advantage of lower carbon portfolios with a track record of outperforming the market. The One Planet group of long-term investors and SWFs is now developing a carbon sensitive investment framework, for instance. The asset owner-led Transition Pathways Initiative (TPI) is looking to 'management quality' – from the acknowledgment of carbon risk to its incorporation in strategic decision-making – as a key indicator of future performance.[73]

By comparison, there remains limited understanding of how carbon risks are likely to play out in national economies. Central banks and regulators are moving to understand these carbon risks. In March 2018, the governors of the UK, French and Dutch central banks called for growing regulatory oversight, including the potential development of forward-looking 'carbon stress' tests over longer time horizons, and a shift from voluntary to mandatory disclosures. The first technical challenge, according to Governor Villeroy de Galhau of the French Central Bank, is 'how can we elaborate on

[69] Nueman, W. (2018), 'To Fight Climate Change, New York City Takes On Oil Companies', *The New York Times*, 10 January 2018, https://www.nytimes.com/2018/01/10/nyregion/new-york-city-fossil-fuel-divestment.html (accessed 30 Apr. 2018).
[70] Climate impacts, through extreme weather events and rising sea levels, for instance, and the costs of climate adaptation are a critical issue developing countries and financial markets alike (particularly the insurance industry), but fall largely beyond the scope of this paper.
[71] TCFD (2017), 'Mike Bloomberg and FSB Chair Mark Carney Announce Growing Support for the TCFD on the Two-Year Anniversary of the Paris Agreement', Press Release, 12 December 2017, https://www.fsb-tcfd.org/wp-content/uploads/2017/12/TCFD-Press-Release-One-Planet-Summit-12-Dec-2017_FINAL.pdf (accessed 5 Apr. 2018).
[72] Asset allocation strategies i.e. how much is invested in debt (low-risk government and higher-risk corporate bonds), equities (publicly listed shares) and other assets (including cash, infrastructure etc.) will vary depending on this time frame, and on an investor's risk threshold.
[73] TPI (2018), *The Toolkit,* LSE Grantham Institute, http://www.lse.ac.uk/GranthamInstitute/tpi/the-toolkit/.

the link between climate scenarios and economic scenarios?'[74] Ratings agencies are also beginning to consider exposure to climate and carbon risks as factors in sovereign credit ratings, which may in time affect the cost of borrowing.[75] This presents a particular challenge for developing countries with fossil fuels – which tend to be highly reliant on FDI and external debt and heavily exposed to volatile export revenues.

Taken together, these shifts may have implications for the speed of transition and access to finance. While MDBs and donors are increasing their climate finance commitments, the ability of the least-developed countries to access these mechanisms remains unclear. At the same time, green finance and other sustainable investment mechanisms are growing rapidly, but regulatory shifts including the introduction of BASEL III may constrain longer-term lending to emerging markets.[76] This presents a challenge for investment into RE and clean energy systems, which tend to rely on capital markets for a higher percentage of their finance than upstream and thermal power investments.[77] MDBs and long-term investors may help de-risk and facilitate longer-term capital where these barriers are present.

[74] Hook, L. (2018), 'Central bank chiefs sound warning on climate change', *Financial Times*, 9 April 2018, https://www.ft.com/content/888616d6-3b07-11e8-b7e0-52972418fec4 (accessed 9 Apr. 2018).

[75] To date, this conversation has tended to focus on country vulnerability to climate impacts (e.g. sea-level rise, extreme weather events). The unfortunate reality is that those developing countries most affected by climate impacts, e.g. low-lying island states, are also those most vulnerable to credit downgrades. Participants at the project workshop held in London in September 2017 agreed that the first climate-related downgrades would represent a 'double injustice', with those hardest hit also seeing their access to finance most constrained.

[76] BASEL III was introduced to the objective of reducing systemic risk in the banking sector. By penalizing lending beyond five years, it is likely to further incentivize short-term lending. It also adds a 'risk premium' to investment in emerging markets, requiring banks to hold a punitive amount of capital against lending to countries that are not investment grade. See Bank for International Settlements (2017), *Basel III: Finalising post-crisis reforms*, Basel Committee on Banking Supervision, https://www.bis.org/bcbs/publ/d424.pdf (accessed 30 May 2018).

[77] Around 90 per cent of investment fossil fuel supply and thermal generation was financed directly from the balance sheet of IOCs, with the remaining 10 per cent covered by project finance (split roughly 50:50 between private sources, e.g. commercial banks, and public sources, e.g. government and multilateral loans), while RE investment relies on project finance for closer to 50 per cent of total investment. See IEA (2018), 'World Energy Investment 2017', IEA/OECD, https://www.iea.org/publications/wei2017/ (accessed 30 May 2018).

3. Carbon Risks for Developing Countries with Fossil Fuels

To understand how the uncertainties described in Chapter 2 might affect fossil fuel producing countries, it is useful to review the linkages that tend to form between the fossil fuel sector and the wider economy. This chapter considers how these linkages might translate into carbon risks at the country level, with a focus on export revenues and fossil fuel supply to domestic energy and industrial infrastructure as the key dynamics. To illustrate how these risks might play out in practice, this chapter discusses some potential production, consumption and revenue scenarios for Ghana, an early stage and expanding oil and gas producer, and Tanzania, an experienced onshore gas producer with a relatively large-scale offshore gas discovery. However, these examples have broader relevance for a range of developing countries.

The fossil fuel sector as a driver of economic development

Well-managed fossil fuels can contribute to economic development and long-term wealth generation in a number of ways, including through:

- The investment and revenues that fossil fuel projects generate – including signature bonuses, royalties, taxes and other fees paid by oil companies, and income from fossil fuel sales. These usually accrue to one or more branches of government and can, in turn, support budgetary expenditure (including the use of foreign exchange for imports), capital expenditure (financing large-scale infrastructure for instance), long-term savings (e.g. through a SWF), as well as enhancing access to finance (due to credit enhancement).
- The use of fossil fuels in the economy whereby the government's 'share of production' and/or 'buybacks' from the producer company are consumed in-country, where there is appropriate infrastructure in place. Fossil fuel inputs are primarily used in energy generation, particularly coal and gas in thermal power plants, and as feedstock for heavy industry – including coking coal for steel, and oil and gas in petrochemicals, fertilizers and plastics manufacturing. Domestic fossil fuel production may therefore support demand growth in the power, industrial and transport sectors or replace imported fuel and other oil-based products at a lower cost.[78]

However, there is a long list of potential negative governance and economic 'side effects' endured by countries that come to rely on the sector, often grouped as 'resource curse risks' (Figure 7).[79]

[78] Note that few low or middle-income producers have domestic oil refinery capacity, due to both the expense of refinery infrastructure and the economies of scale required to make refinery activities commercially viable. The exceptions – Nigeria, Angola – are among the largest oil producers in the world. Accordingly, oil exporters generally depend on imports for domestic consumption.
[79] Stevens, P. and Lahn, G. (2015), *The Resource Curse Revisited*, Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/sites/files/chathamhouse/publications/research/20150804ResourceCurseRevisitedStevensLahnKooroshyFinal.pdf (accessed 31 May 2018).

Standard advice given to producer countries in order to avoid negative resource curse impacts normally centres around support for 'good governance' of the sector. This is particularly notable around the transparency of revenue and other payments to government, and where the effectiveness of fiscal measures to stabilize and invest fossil fuel revenues are concerned. As noted in the introduction, there is also now growing emphasis on the development of economic and energy 'linkages' between the fossil fuels sector and the wider economy. Economic linkages may include direct employment within the oil and gas sector, indirect employment in industries that supply the sector, and broader private sector development where new markets for goods and services open up as a result of incoming capital and workers. Energy linkages often focus on the utilization of associated (or non-associated) gas in the domestic economy.

The global shift to a decarbonized energy system, discussed in Chapter 2, challenges many of the prevailing assumptions that underpin fossil fuel driven development pathways. Potentially sharper declines in export markets as a result of decarbonization may translate into lower overall revenues than anticipated, reduced investor interest in new fossil fuel developments and 'stranded' resources and assets.[80] Subsidized or 'cheap' domestic fossil fuel consumption and the political economy that emerges around the sector may act as a barrier to sustainable economic diversification, and undermine opportunities to harness new energy technologies and support 'green growth'.[81] These factors suggest that carbon risks have the potential to exacerbate and change the nature of many well-known resource curse risks (Figure 7).

Figure 7: Resource curse risks through a carbon lens

	Mechanisms of wealth creation	'Resource curse'/carbon risks
Fossil fuel investment and revenues	• Ability to pay international debts and 'graduate' from aid. • Support for budgetary expenditure including public services and core infrastructure. • Foreign exchange (FX) flows facilitate payment for foreign goods. • Establishment of savings for future generations e.g. through SWFs.	• Economic dependence on volatile and shrinking global commodities markets, uncertainty regarding time frame for declining demand. • Political and public expectations re. rents from the fossil fuel sector and risk of locking in high 'social cost' of transition (real or perceived). • Management of fiscal impacts incl. 'boom-bust' economy, Dutch disease, imbalance of trade compounded by longer-term uncertainty re. fossil fuel demand and exposure to international carbon risks through foreign investments.
Economic, energy and industrial linkages	• Access to energy e.g. development of gas-to-power infrastructure, fuel switching (e.g. gas displacing charcoal, HFO/LFO), reduced reliance on imports. • Industrial development based on fossil fuel inputs e.g. petrochemicals, gas-/coal-based fertilisers, steel, cement. • Local content (employment, services, procurement) for the fossil fuel sector.	• Diversification into high-carbon sectors locks-in carbon-intensive infrastructure/locks-out of emerging technologies. • Energy and industrial pathways promote rising fossil fuel demand, leading to further domestic production and/or import dependency (and in turn, pressure on FX). • Uncertain time frame for 'depletion-based' economic diversification. • Political economy and incumbent energy and industrial interests obstruct low-carbon transition.
Access/ positioning for finance	• Growing FDI, GDP and cash flow reflected in sovereign credit rating. • Lower cost of borrowing on international markets. • Access to 'oil-backed' loans from consumer countries and traders.	• Sovereign credit rating downgrades due to carbon risk exposure increase cost of borrowing. • Access to climate finance and green finance mechanisms affected due to perception of 'subsidizing twice'. • Vulnerability to sub-optimal financial structures e.g. securitizing finance against oil incomes.

Source: Compiled by the authors.

[80] In the context of decarbonization, this refers to those physical assets that have received investment, which lose their commercial value as other technologies displace demand for the product. See Glossary for full definition.
[81] Seto et al. (2016), 'Carbon Lock-In: Types, Causes, and Policy Implications', *Annual Review of Environment and Resources,* Vol. 41:pp. 425–452, https://doi.org/10.1146/annurev-environ-110615-085934 (accessed 31 May 2018).

What can scenario analysis tell us about carbon risks?

For the reasons outlined in Chapter 2, scenarios cannot be taken as a reliable guide to the future, nor are they intended to be. Scenarios can help provide a common basis for the discussion of national development plans and the role of fossil fuel within them. They can also help bring the relevant planning and decision-making centres together, and encourage consideration of the trade-offs associated with different development pathways and the resilience of plans to gradual and more disruptive change.

Scenarios covering several decades are often drawn up by fossil fuel producing countries, or for them. They typically chart either production and revenues or production and domestic consumption, but rarely the interaction of all three. Past experience demonstrates that new and prospective fossil fuel producers tend to overestimate the opportunities presented by fossil fuel development, and underestimate the risks. These expectations may be exacerbated by the scenarios and projections produced by international organizations, development advisers and private sector partners, which often assume reliable investment and international demand, and optimistic export prices. These scenarios also often fail to factor in domestic infrastructure investment needs, and the levels of domestic demand and prices that would be required to facilitate domestic use of the resource.

> Ghana and Tanzania illustrate the potential interaction between fossil fuel production, revenues and consumption under a range of credible climate scenarios.

In order to understand how carbon-related trends might intersect with common resource curse challenges in different contexts, this chapter uses simple modelled scenarios for two countries with different fossil fuel reserves and economic contexts – Ghana and Tanzania. They illustrate the potential interaction between fossil fuel production, revenues and consumption under a range of credible climate scenarios.[82] A full methodology and sources for the modelled country scenarios are presented in Annex III.

The range of fossil fuel revenues under different climate constraints

A producer government's net revenues are shaped by the policies, regulations and contracts that guide the development of fossil fuel reserves, including the operator's and government's respective share of production (and related capital and operating expenditure), the fiscal regime that the operating company is subject to (bonuses, royalties, taxes), and international market demand and prices. Many of these factors – particularly contractual terms – are not publicly available. International prices, meanwhile, will be affected by a number of drivers in addition to supply and demand fundamentals, including the effect of geopolitical risk and climate impacts on fossil fuel markets (see Box 4). For the purposes of this paper, gross revenues to government are calculated as:

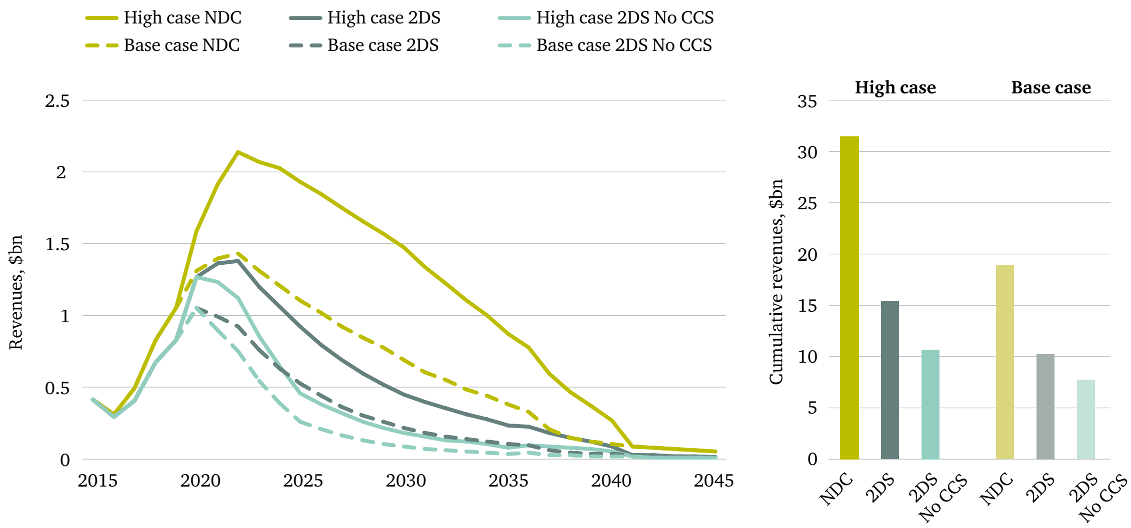
([Export level] × [Market price] - [Total production & transport costs]) × [Government share]

The price inputs are based on figures for market demand and costs in the TIAM-UCL model, which were cross-checked against IEA projections. Gross revenues are charted under three climate scenarios – NDC, 2D, and 2D No CCS – presented in Chapter 2 of this paper.

[82] Full methodologies for the country-level modelled scenarios and the TIAM-UCL global energy model (which provides the market price inputs) are provided in annexes II and III, respectively.

Oil production is typically exported, unless the scale of the production is sufficient to support domestic refinery activities. Figure 8 shows Ghana's potential oil export revenues over a 30-year period to 2045. Production in a 'high case' – where all proven reserves are developed – could deliver a cumulative $31.4 billion in revenue to 2045 under an NDC scenario, compared to just $15.3 billion under a 2D scenario and $10.6 billion under a No CCS scenario. In the NDC, 2D and No CCS scenarios, average annual revenues stand at $1 billion, $720 million and $510 million, respectively. Production in a 'base case' – where only those projects that are currently under development come online – could deliver $18.9 billion under an NDC scenario, compared to $10.2 billion under a 2D scenario and $7.7 billion under a No CCS scenario. Their respective average annual revenues stand at $630 million, $340 million and $260 million. The difference between cumulative and average annual revenues in the NDC and No CCS scenarios is around 50 per cent.

Figure 8: Ghana net oil export revenues, net of production costs, under different climate scenarios, 2015–45



Source: UCL/Chatham House, 2018. See Annex III for full methodology.
Note: High case for production = all proven reserves are developed; Base case for production = those reserves currently under development come online; Low case for production = N/A.

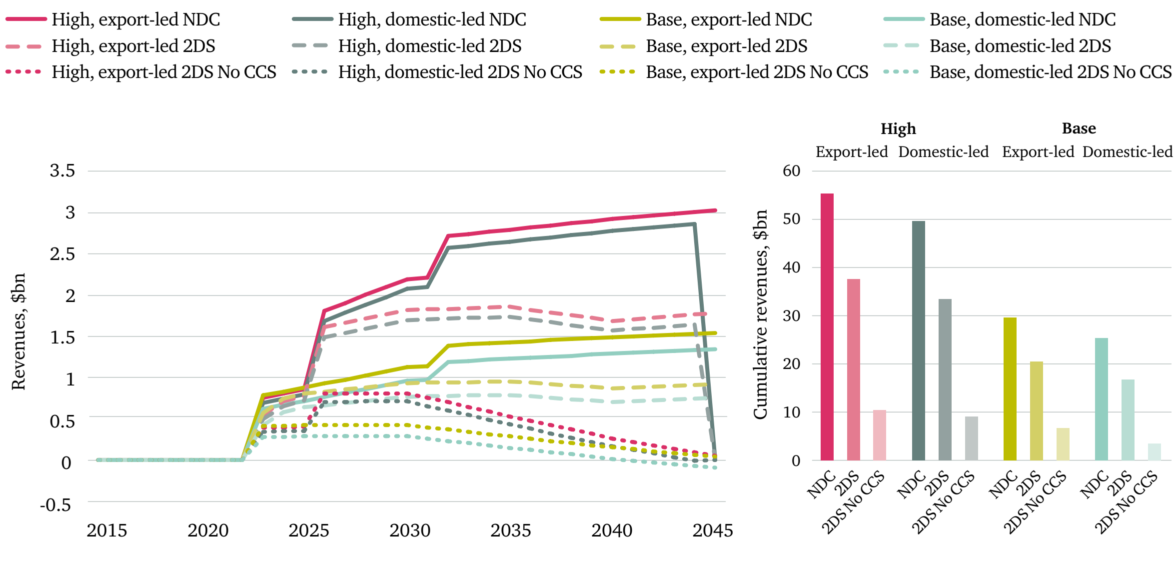
Where gas discoveries are made, governments often plan to deploy some or all production in the domestic market, where it can be made economically viable. The modelling for this paper also explored the potential outcomes for gas production in Tanzania, which has larger gas reserves than Ghana, and is at an earlier stage of production. Tanzania plans to allocate an as yet unspecified percentage of its forthcoming offshore gas production to the domestic market.

Figure 9 shows the range of potential gas export revenues. Gas production in the high case – with four LNG trains in use – could generate cumulative revenues of $49–$55 billion under an NDC scenario, $33–$37 billion under a 2D scenario, and $9–$11 billion under a No CCS scenario. These ranges depend on how production is allocated to the domestic and export markets – prioritizing supply to the domestic market results in lower revenues. Cumulative revenues differ by 80–82 per cent between an NDC and a No CCS scenario; gas exports typically incur higher production and transport costs than oil, particularly where liquefied natural gas (LNG) infrastructure is required. At the same time, gas demand is more sensitive than oil to some of the uncertainties set out in Chapter 2, particularly lower rates of CCS deployment, given its role in the power sector.

A similar pattern is evident for average annual revenues, which range from $2.2–$2.5 billion, $1.5–$1.7 billion and $410–500 million under the high case, depending on the climate scenario, and from $1.1–$1.3 billion, $750–$920 million and $160–$300 million under the base case, which assume a slower rate of production, with two LNG trains in operation (depending on how production is allocated between export and domestic markets). By contrast, in 2014, the IMF estimated that Tanzania's revenues from offshore gas production would plateau at $3.6–$3.7 billion per year from 2029 to 2044 under a high case, and $2.5–$3 billion from 2025 to 2039 under a base case, assuming that production began in 2021,[83] and that gas prices averaged around $11 per million British thermal units (MMBtu).[84] The IMF now acknowledges that these projections were 'over-optimistic'.[85]

A low case for production – where there is no final investment decision and Tanzania's offshore gas resources remain undeveloped – would mean no export revenues or additional fossil fuel flows to the domestic market. While this may be a politically unpalatable scenario, there is a risk that increasing global uncertainty regarding long-term gas demand and price outlooks (see Box 4), political risk, rising project costs and difficulty accessing finance for gas infrastructure could contribute to such an outcome, especially in light of the repeated delays that Tanzania has already experienced. In such a case, Tanzania would only receive low-level revenues from the existing sale of onshore gas to the domestic market (not shown in Figure 9). This raises the importance of planning for the 'worst case' scenario, particularly where national energy and industrial plans are dependent on the development of domestic supply.

Figure 9: Tanzania net gas export revenues under selected production and climate scenarios, 2015–45



Source: UCL/Chatham House, 2018. See Annex III for full methodology.
Note: Production cases – High case assumes four LNG trains; Base case assumes two LNG trains; Low case assumes no final investment decision (not shown). Market allocation – Export-led assumes only 20 per cent of production to the domestic market; Domestic-led assumes that production meets domestic demand projections first, with the remainder exported.

[83] The IMF ran four LNG train and two LNG train scenarios, excluding taxes and royalties. It is assumed that each LNG train has a production capacity of 5 million tonnes per annum (MTPA).
[84] Compared to our price assumptions (between 2015 and 2050) of $9.6 to 12.6 under an NDC scenario, $8.9 to $11 under a 2D scenario and $6.2 to $10.5 under a 2D No CCS scenario. See Annex III for full methodology.
[85] Ng'wanakilala, F. (2017), 'IMF says Tanzania Revenue Projections "Optimistic" and Could Delay Projects', 26 June 2017, *Reuters,* https://www.reuters.com/article/tanzania-economy-imf/imf-says-tanzania-revenue-projections-optimistic-and-could-delay-projects-idUSL8N1JN47R (accessed 31 May 2018).

While sweeping conclusions cannot be drawn from a sample of two, there are two notable observations from the revenue scenarios:

- First, the range of cumulative gas export revenues under different climate scenarios appears greater for gas than for oil. The revenues of the various production scenarios differ by up to 80 per cent for Tanzania's gas, compared to around 50 per cent for Ghana's oil. The relatively higher sensitivity of gas demand under more constrained climate scenarios appears to be a key factor here, as well as the greater levels of infrastructure investment associated with gas production and transport.
- Second, the trajectories of annual revenues for oil and gas vary significantly, although the different levels of production between the two countries are of course a factor. Under all scenarios, Ghana's oil revenues appear to peak at around 2022, before declining steadily until the resource is depleted in around 2040. By contrast, depending on the production, market allocation and climate constraints, Tanzania's gas revenues could in theory enter into decline in the 2030s, plateau through the 2040s and beyond, or stop abruptly in 2045.

There are three further observations where Tanzania's gas revenues are concerned:

- First, supplying the domestic market reduces potential revenues. Where a greater share of production is allocated to the domestic market (assuming that additional gas is produced to meet domestic demand on top of exports, as opposed to a flat 20 per cent share of production as in the export-led scenario), cumulative export revenues under both production cases fall by around \$5 billion, \$4 billion or \$3 billion, respectively (depending on the climate scenario), as production expands to meet export commitments *and* growing domestic demand.[86]
- Second, higher production and high domestic use results in rapid depletion of the resource. The high case with a domestic-led allocation (dashed lines in Figure 9), means that (currently estimated recoverable) gas reserves are completely depleted by 2045, when annual export revenues collapse.
- Third, the most constrained climate scenarios suggest a shorter time frame for production. Under a No CCS scenario (dotted lines in Figure 9), export demand for gas falls almost a decade earlier; as a result Tanzania's annual revenues could decline from 2030. Under such circumstances, production would be loss-making by the early 2040s, as annual production and transport costs begin to exceed revenues. This may increase the prospect of stranded investments and/or undeveloped resources.

Revenue and investment risks

While the challenges of managing dependence on a volatile export commodity are not new, they are likely to evolve under growing carbon constraints. Through previous boom and bust cycles for commodities, it has typically been assumed that high demand and high prices will return; indeed the idea of using the downturn to 'prepare for the next boom' has underpinned many 'good governance' narratives in recent years.[87] This paper's analysis gives some indication of the potential range of

[86] The assumption is made that LNG facilities would need to operate at full production in order to remain commercially viable; therefore, the domestic allocation is *in addition* to an indicative export level (two or four LNG trains), pushing total production up. Lower revenues due to higher domestic market allocation may of course be offset by a lower level of imports and the associated costs. See Annex III for full methodology.
[87] The concept of 'using the downturn to prepare for the next boom' has been prominent at the many conferences and seminars that the authors have participated in and in conversations with country decision-makers in recent years.

revenues that may occur under three credible climate scenarios, in addition to the many other drivers of global supply and demand and, in turn, price and volatility (see Box 4). The material impact of these trends will of course be determined by the country context.

The range of possible supply and demand volumes under different climate scenarios also suggests that some oil and gas assets may go undeveloped. For instance, where new Norwegian oil production is under consideration, analysis from the Stockholm Environment Institute (SEI), suggests that only production with a break-even point of $60 per barrel or less could be commercially viable in a 2°C world (assuming that the lowest-cost fossil fuel projects come to market first).[88] It is worth noting the difference between the break-even price, which underpins the decision to invest in new capacity, and the shut-in price, which determines whether to continue or halt existing production (effectively, whether oil prices cover the short-run variable costs of production).[89]

> It seems prudent for prospective and existing producers to consider longer-term downside price and cost scenarios and plan for the 'worst case' scenario for fossil fuel investment and revenues.

The 'winners' and 'losers' in the race to secure investment in fossil fuels will ultimately be defined by a combination of factors, including the type and scale of resource, the cost of production, the wider investment environment (political risk, sovereign risk, cost of capital) and the likely markets a producer can lock-in. Nonetheless, it is reasonable to assume an increasingly competitive market for the remaining 'burnable' carbon budget, which will place marginal producers and those still at the exploration stage or awaiting final investment decisions at a distinct disadvantage, in terms of securing investment in the coming years. For these reasons, it seems prudent for prospective and existing producers to consider longer-term downside price and investment scenarios and plan for the 'worst case' scenario for fossil fuel investment and revenues.

Box 4: Volatility and changing market fundamentals

The price scenarios presented in this paper provide a picture of possible long-run average and cumulative revenues, but they do not reflect shorter-term price volatility. Several dynamics will affect oil and gas prices in the short to medium term. These include upward price pressure from major producer countries, which need higher prices to support their export-dependent budgets (particularly to cover rising welfare, civil service and subsidy costs), as demonstrated by the OPEC-plus decisions (led by Saudi Arabia and Russia) to cut production in 2017/18 in order to shore up low oil prices.[90] At the same time, downward pressure from commercially-produced US shale oil provides an effective 'price ceiling' for oil.

International contract and spot prices of natural gas exhibit much greater variance between regions than oil prices, despite still being partly linked to oil prices (although gas prices are becoming more independent with greater trading of LNG). LNG spot prices are likely to be affected by shifting supply and demand fundamentals. For example, new supplies of natural gas following Qatar's decision to lift the moratorium on its Northern Field, and increasing LNG production from the Russian Arctic – could increase gas supply and 'loosen' the market in the

[88] See Down, A. and P. Erickson (2017), *Norwegian oil production and keeping global warming 'well below 2°C'*, SEI discussion brief, Stockholm: Stockholm Environment Institute, https://www.sei.org/publications/norwegian-oil-production-and-keeping-global-warming-well-below-2c/, (accessed 31 May 2018).
[89] Our colleague Paul Stevens has written extensively on this issue in the context of OPEC/US shale dynamics. See, for example Stevens, P. (2014), *Deja Vu for OPEC as Oil Prices Tumble*, Chatham House Expert Comment, 1 December 2014, https://www.chathamhouse.org/expert/comment/16368 (accessed 31 May 2018).
[90] Fattouh, B. and Dale, S. (2018), 'Peak Oil Demand and Long-Run Oil Prices', Oxford Institute of Energy Studies, https://www.oxfordenergy.org/publications/peak-oil-demand-long-run-oil-prices/ (accessed 31 May 2018).

coming few years. In the longer term, delayed and cancelled LNG investments, due to such uncertainties, may result in the market tightening up again thereafter, sending prices higher.

Other, less predictable drivers also play a role. Political decisions in major markets – such as China's 2017 closure of coal-fired power generation in order to reduce air pollution and consolidate the domestic coal industry – will inevitably affect demand for, and thus the price of, other fossil fuels. The perception of geopolitical risk can raise the prospect of short-term oil and gas supply disruption, and prompt sporadic price volatility, as seen following the Trump administration's announcement that the US would withdraw from the Iran nuclear deal and re-impose sanctions on Iran in May 2018.

Over the longer term, however, the fundamentals of demand will change. Rising temperatures are already increasing demand for cooling of air and water. Climate impacts – for example, extreme weather events that lead to sudden changes in energy supply or demand due to the shutdown of affected production, refineries, power plants or transmission and distribution infrastructure and their knock-on effects – could increase price volatility, while the prospect of electricity outages or fuel shortages may encourage consumers to turn to decentralized power sources for energy security. Many are now raising the prospect of spikes in oil and LNG spot prices, due to the relative lack of upstream investment in recent years and the increasing reluctance of IOCs to invest in longer-term projects.[91] Demand surges would prompt importers to increase 'national energy security' measures (as seen following the oil price spikes of the 1970s and over the last decade), including rapidly increasing energy efficiency and RE investment, which would effectively destroy long-term fossil fuel demand.

The fiscal impact of rising domestic fuel demand

As more fuel is diverted to the domestic economy, countries face a choice between making less production available for export, or increasing production and depleting reserves at a faster rate. This is a problem because, as shown earlier, domestic use does not typically generate the same level of revenue as exports; it is sold either at cost price (plus a margin for processing, transportation, etc.) or subsidized, in order to incentivize use (this is common with gas and LPG, but also oil fuels).[92] Ghana is unusual here; its gas production, which is all destined for domestic consumption,[93] has not reduced the consumer price below import costs.[94] In addition, revenues from domestic sales and other taxes and duties will be in the local currency rather than foreign exchange.

This can present a fiscal challenge, as foreign exchange reserves are crucial for a county's ability to make international payments. When a product can be exported, the more that is sold domestically, the less foreign exchange is generated. In addition, US dollars are generally the preferred payment for IOCs and foreign investors, given their low volatility and their role as a benchmark currency. IOCs and foreign investors are typically wary of investing in projects to supply the domestic market in countries with 'non-convertible' currencies, given the exchange rate volatility that this may expose them to. This can result in significant fiscal dependencies, with countries relying on the foreign exchange from the export commodity (LNG or crude oil) to finance gas buybacks for the domestic market.

This paper illustrates this risk by charting upstream fossil fuel production against a range of simple energy demand trajectories. These are purely exploratory and are presented in Figure 10, alongside

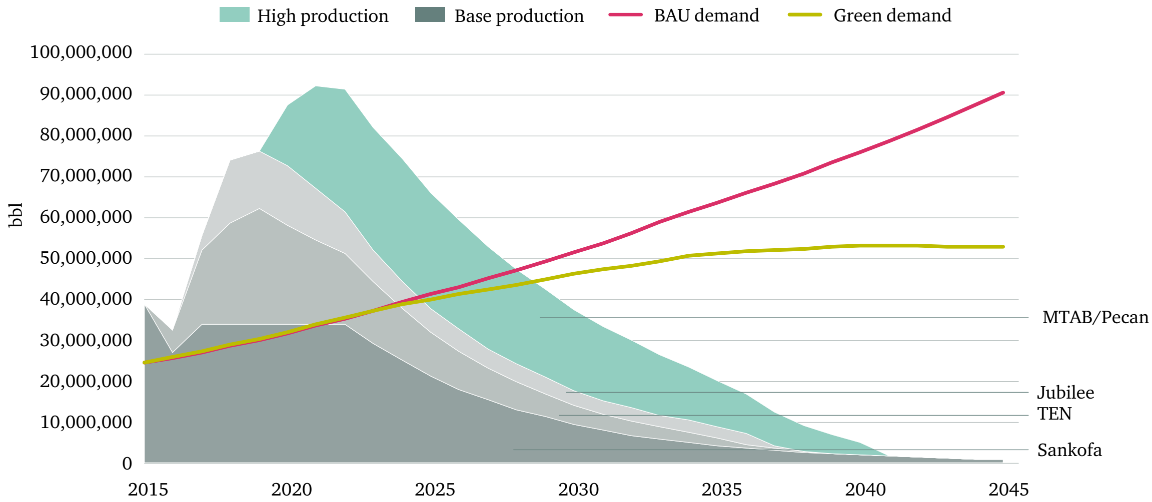
[91] Sheppard, D. and Raval, A. (2018), 'Oil producers face their 'life or death' question', *Financial Times*, 19 June 2018, https://www.ft.com/content/a41df112-7080-11e8-92d3-6c13e5c92914 (accessed 19 Jun. 2018).
[92] The exception, noted above, is where large-scale LNG infrastructure requires set export volumes to ensure a return on investment, in which case gas for domestic use is produced *over and above* gas for export – this still has foreign exchange implications.
[93] Although, as with Tanzania, there are tentative plans to export electricity to neighbouring countries.
[94] Jubilee Field associated gas is sold to the Ghana National Gas Company (GNGC) at $2.9/MMBtu. Gathering, processing and transportation plus a regulatory levy increases the price to $8.48/MMBtu. This is roughly benchmarked with imports of Nigerian gas through the West African Gas Pipeline at $8.5/MMBtu.

official demand projections (the 'official' trajectory). They draw on key drivers of growth (GDP, sector growth, population) and energy and technology assumptions:

- Business-as-usual (BAU) – based on the current and planned energy mix, in particular the national projections for natural gas use; and,
- Green – showing higher RE penetration, greater energy efficiency and the application of selected low-carbon technologies including EVs.[95]

Figure 10 shows Ghana's oil production against a range of domestic oil demand trajectories. Ghana's imports of oil products currently meet the bulk of national oil demand, and while an expansion of its small-scale refinery capacity may supply some additional product to the domestic market, a significant increase in import-dependence is anticipated. Ghana could become a net oil importer between 2025 and 2030. At this stage, there would be implications for its foreign exchange due to the combination of decreasing production (and export revenues) and increasing demand, and thus imports. The lower 'green' demand trajectory, shown in green, could mitigate this over time.

Figure 10: Ghana oil production and demand under selected scenarios, 2015–45

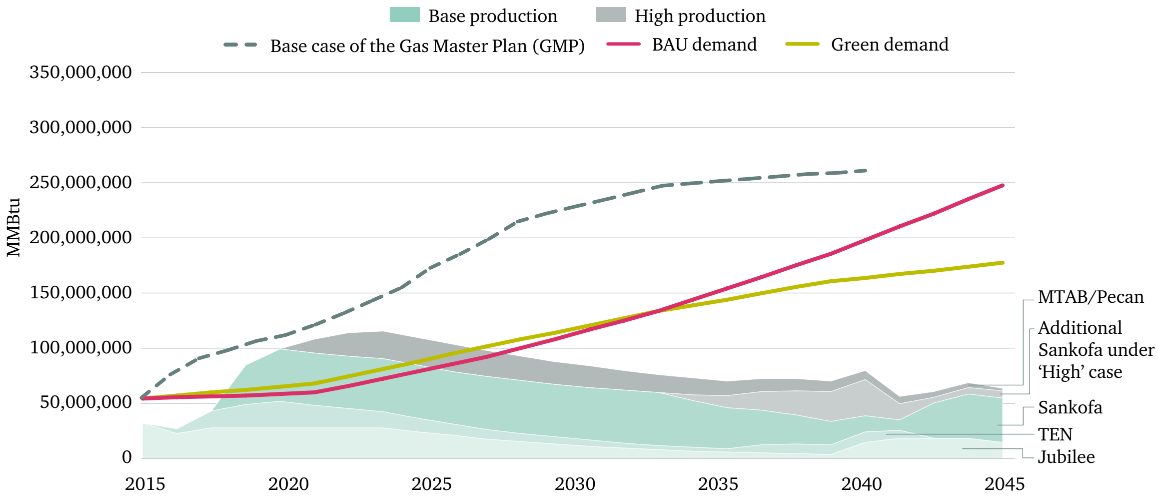


Source: UCL/Chatham House, 2018. See Annex III for full methodology.
Note: High case for production = all proven reserves are developed; Base case for production = those reserves currently under development come online; Low case for production = N/A.

Figure 11 shows Ghana's domestic gas production against a range of demand scenarios. It suggests that Ghana will be a net gas importer in the early 2020s (as per Ghana's Natural Gas Master Plan), it will be able to meet its own demand for a few years as new gas supplies com online in the mid-2020s, and will then become import-dependent again from the mid- to late-2020s, as gas demand outpaces supply. While import infrastructure is in place, with the West Africa Gas Pipeline and plans for an LNG terminal, these scenarios present real energy security and fiscal stability questions. Lower and more flexible demand growth, with higher efficiency and RE deployment, could mitigate these risks by reducing import dependence and related current account stress.

[95] Full methodologies for the country-level modelled scenarios and the TIAM-UCL global energy model (which provides the market price inputs) are provided in Annexes II and III, respectively.

Figure 11: Selected gas supply and demand scenarios for Ghana, MMBtu



Source: UCL/Chatham House, 2018. See Annex III for full methodology.
Note: High case for production = all proven reserves are developed; Base case for production = those reserves currently under development come online; Low case for production = N/A.

A closing window for economic diversification

Economic diversification away from the sector is now seen as the 'litmus test' of successful fossil fuel-led growth. For most developing countries, reducing dependence on exports of raw materials and imports of consumer goods is also a development priority. At the same time, as outlined above, development assistance to the fossil fuel sector has increasingly focused on the development of economic linkages between the fossil fuel sector and the wider economy. This means leveraging fossil fuel revenues, fossil fuel flows and the sector itself (through local employment and local content) for broad-based economic growth. For economic diversification to be sustainable non-oil sectors of the economy must become competitive without dependence on subsidized or 'cheap' inputs from the fossil fuel sector, before the sector's production begins to decline.

The productive lifespan of upstream assets typically spans decades. In many cases, the inflows of revenue and FDI will already have begun to influence economic dependence at an early stage. Under 'BAU' conditions, there is a compelling argument that slowing production and extending the export plateau phase could help enhance wealth creation from the sector, as the government, the private sector and the wider workforce have longer to develop the necessary institutions and capacities.[96] Under the most carbon-constrained scenarios, this may not be feasible; the No CCS scenario in Figure 9 shows Tanzania's gas revenues plateauing for up to a decade (compared to 20 plus years in the NDC and 2D scenarios) and declining from 2030. These uncertainties suggest that new producers cannot afford to wait to reach full production before concentrating on stimulating economic diversification.

The prospect of declining global demand before an asset's expected lifespan is reached could, in theory, encourage the rapid depletion of reserves. This is often described as the 'green paradox' effect, where countries – particularly those with larger reserves or higher-cost production – compete for what demand remains. Recent research has found little evidence of policy decisions that constrain carbon being a driver

[96] Stevens and Lahn (2015), *The Resource Curse Revisited*.

for this green paradox effect, except in a few cases of oil.[97] Nonetheless, it highlights the kinds of trade-offs that governments have to consider when planning and pacing fossil fuel production – including the real cost of rapid financial inflows (including the risk of corruption and rent-seeking), and the risk of infrastructure lock-in and/or stranded infrastructure (gas, thermal power, oil refineries) against the 'opportunity costs' of capturing more value domestically.

The risk of delays and disruption

Ghana's recent experience with associated gas illustrates the impact that delays in investment and project delivery can have. Gas deliveries to the power sector and the completion of gas-fired power generation were delayed throughout 2014–15 (see Box 5). This exacerbated the power crisis (or 'Dumsor', meaning 'off, on') and led to dependence on 'power barges' supplied by imported fuel oil, which is an expensive and emissions-intensive fall back. It also contributed to a change of government in the 2016 elections.

Box 5: The impact of delays to gas utilization in Ghana

Delays in bringing associated gas to the domestic market have hindered Ghana's energy security and economic diversification and its commitment not to flare.

When the first oil contracts for the Jubilee field were signed, the intention was to allow the Ghana National Petroleum Company (GNPC) to own and process the Jubilee gas through a public–private partnership (PPP). GNPC was in talks with the World Bank and private entities for the financing of the processing plant.[98] In 2008, the new government decided to set up a separate gas company, Ghana National Gas Company (GNGC), to be responsible for development of the processing plant and to manage the midstream gas gathering, processing and transportation. This delayed the implementation programme by two years, and led to the use of future oil revenues as collateral for a $3 billion Chinese Development Bank facility, $1.5 billion of which financed the gas plant.

This delay directly affected Ghana's energy security. Load-shedding (the deliberate shut down of parts of an electricity system to prevent total system failure) has been a recurrent feature of Ghana's power sector since the 1980s. This was originally prompted by reduced levels of water in hydro-electric dams but in 2012, load-shedding began when gas supply from the West Africa Gas Pipeline (WAGP) was cut off after it was damaged by the anchor of a ship off the coast of Benin. Had the processing plant been constructed in time, domestic gas would have been available to replace the curtailed Nigerian gas. It wasn't, and the country faced periodic power shortages until 2015.

It also affected Ghana's economy. First, the power crises or 'dumsor' is estimated to have cost the energy sector over $1 billion,[99] and the wider economy somewhere between $320 million and $924 million annually through business losses, according to the Institute of Statistical Social and Economic Research (ISSER).[100] Second, Ghana's no flaring policy was suspended in 2014 and operator Tullow Ghana began flaring as it was no longer safe to continue re-injecting gas into the oil wells, and because it would begin to affect oil production volumes. Third, by financing the gas project with $1.5 billion of public debt rather than allowing private capital to come in and deliver it, the government lost the opportunity to spend on critical social investment such as education, health and infrastructure, which do not attract investment as easily. Fourth, gas revenues are affected by non-payment from power generation companies, which, in turn, are not paid by power distribution companies. Revenues from offshore gas are owed to the Petroleum Holding Fund (PHF), which was established by the Petroleum Revenue Management Act in part to help diversify the economy. According to the Auditor General, GNGC owed the PHF over $2 billion (comprising revenues and penalties) by the end of 2016.

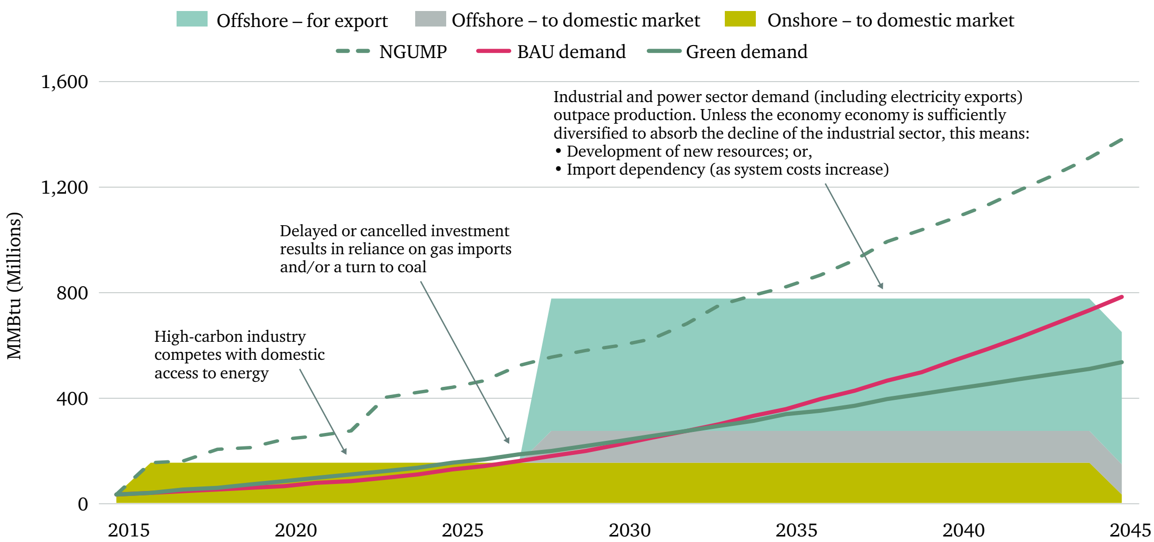
[97] Buar, N., McGlade, C., Hilaire, J. and Ekins, P. (2018), 'Divestment prevails over the green paradox when anticipating strong future climate policies', *Nature Climate Change*, January, https://www.nature.com/articles/s41558-017-0053-1 (accessed 31 May 2018).
[98] Rigzone (2009), 'GNPC Taps Oando for $1B Jubilee Project', 5 October 2009, https://www.rigzone.com/news/oil_gas/a/81011/gnpc_taps_oando_for_1b_jubilee_project/ (accessed 31 May 2018).
[99] ACEP (2017), Liquefied Natural Gas (LNG) Supply to Ghana: The Politics and the Reality, https://new-acep-static.s3.amazonaws.com/publications/Advisory+Paper+on+LNG+2017.pdf (accessed 31 May 2018).
[100] Institute of Statistical Social and Economic Research (ISSER) (2014), Ghana Social Development Outlook (GSDO), Ghana, http://isser.edu.gh/images/Publication_files/Ghana_Social_Development_Outlook_2014__OVERVIEW.pdf (accessed 31 May 2018).

Ghana's experience illustrates both the difficulty of commercializing gas and the potential pitfalls in governance once interests begin to crowd around the sector. In this case, political interests overrode good governance frameworks. It illustrates the burden that may be imposed on a country when debt is used to finance infrastructure against expected future returns from the fossil fuel and power sectors. In this case, the loan taken for the gas plant continues to constrain government revenues and encourages a cycle of non-payment between SOEs: electricity distribution companies fail to pay for power purchased from the generation companies as a result of their inefficiencies and government interference with their operation, which, in turn, results in their non-payment to the national gas company and ultimately to the PHF. In this context, greater private-sector involvement could have encouraged more discipline and accountability in the power sector.

In the case of Tanzania, the country's new offshore gas production was expected to be online in around 2015. This was subsequently delayed until 2018, as a result of global market conditions, and is now expected online between 2023 and 2025. Here again, domestic demand is likely to outstrip supply. Figure 12 illustrates the high level of demand outlined in Tanzania's Natural Gas Utilization Master Plan (NGUMP), compared to the exploratory demand scenarios developed for this paper. Gas demand could outpace production by the late 2020s under most demand cases. It suggests growing import dependency or the risk that industry and power revert to domestic coal supplies to plug the gap.

Moreover, there still appears to be little consideration that Tanzania's gas reserves could remain undeveloped. In a 'low case' for production i.e. where there is no final investment decision and only small-scale onshore production continues, Tanzania's gas demand could surpass production in as early as 2023.

Figure 12: Tanzania's gas supply and demand (base case), with a five-year delay



Source: UCL/Chatham House, 2018. See Annex III for full methodology.
Note: Figure shows a base case for production i.e. two LNG trains, export-led, with production coming online in 2028 instead of 2023.

Infrastructure as a key determinant of carbon risk

One key area of investment that links upstream fossil fuel activities with the wider economy is infrastructure. Upstream energy and industrial infrastructure has particular relevance both to economic development and to a country's long-term exposure to carbon risks. It is also almost always a priority for developing countries when considering how best to invest fossil fuel revenues and the foreign credit that may become available during a fossil fuel boom.[101] Infrastructure choices play a key role in bringing fuels to export and domestic markets; but they are capital-intensive and last for decades. They also tend to promote a level of 'path-dependency' where there are plans to use fossil fuel production to support growing access to energy and industrial development (where the scale of the domestic market and price of production might realistically support this).

Infrastructure including processing plants, refineries, thermal power generation and distribution, and industrial infrastructure are all set out in national development plans. Table 2 sets out the broader range of infrastructure that can require fuel as either energy or feedstock, and thus affect national energy demand and emissions trajectories. Understanding how these areas interact is critical to evaluating the extent of a country's vulnerability to carbon and transition risks. As set out below, most of this infrastructure has direct implications for primary energy consumption and in some cases, for the use of fossil fuels as feedstock.

Table 2: Key infrastructure and direct/indirect energy and feedstock requirements

Infrastructure	Primary energy needs	Fossil fuel feedstock
Direct implications		
Oil and gas sector (upstream, midstream, downstream)		
Drilling platforms	Electricity	n/a
Mines and washing facilities	Electricity	n/a
Pipelines	Electricity	n/a
Liquefaction/gasification terminals	Heat/cooling, electricity	n/a
Ports	Electricity	n/a
Gas processing plant	Heat, electricity	Gas
Refineries	Heat, electricity	Oil
Power sector		
Thermal power plants	Gas, coal, oil fuel	n/a
Dams and hydropower	Water	n/a
Utilities-scale solar	Sunlight	n/a
Wind power	Wind	n/a
Nuclear power	Uranium	n/a
Grids (transmission, distribution)	Electricity	Gas, coal, oil, RE, nuclear
Industry		
Petrochemicals complexes	Heat, electricity	Oil, gas
Steelmaking	Heat, electricity	Coal (coking)
Fertilizer	Heat, electricity	Gas, coal
Cement factories	Heat, electricity	Coal, gas

Source: Chatham House analysis.
Note: This table is not intended to be illustrative, not exhaustive. It includes the energy/power consumption and fossil fuel feedstock required by infrastructure, but not embodied energy or material inputs. Naturally, transport infrastructure in particular is likely to use large amounts of bitumen, and most built infrastructure will require steel and concrete – both currently produced by CO_2 intensive processes.

[101] Whether it is prudent to exploit such opportunities is another question entirely, as has been demonstrated by the experience of Ghana, Mozambique and many other states afflicted by the 'pre-source' curse. The evidence suggests not.

Like the upstream fossil fuel projects they rely on, large-scale power and industrial infrastructure tends to be built with an anticipated lifespan of at least 30 years and often much longer. In order to meet the 'well below 2°C' global target, all new infrastructure would ideally be – or have the capacity to become – carbon neutral. This would mean that infrastructure is either designed to have zero emissions in use, or that emissions are offset in some other way, e.g. through some combination of CCS, afforestation and other NETs. However, CCS is only physically viable in certain places, and is commercially and technologically out of reach for developing markets at present. The ideal approach would be to design and build infrastructure to be as energy efficient as possible, with the capacity to integrate an increasing share of RE from grid or decentralized sources.

Access to sustainable infrastructure investment represents a significant opportunity for those developing countries and regions with the largest 'infrastructure gaps'. An estimated $90 trillion in infrastructure investment is required over the next 15 years, with annual spending of $6 trillion per year, with the global South accounting for around two-thirds of this and energy-sector investments around 60 per cent.[102] As the United Nations Economic Commission for Africa (UNECA) and others have argued, 'greening' infrastructure from the outset – including urban energy and transport systems and industrialization – will lend these countries competitive economic advantages.[103]

Access to sustainable infrastructure investment represents a significant opportunity for those developing countries and regions with the largest 'infrastructure gaps'.

The risk is that infrastructure built today will lock-in energy (and water) demand for decades unless it is replaced or retrofitted – both are far more expensive (not to mention inefficient) options than building to the best available design in the first place. It may also 'lock-out' new technologies and business models as they become more competitive (just as mobile phone and satellite technology bypassed conventional telecoms and banking networks in sub-Saharan Africa). Developing economies would be particularly vulnerable in such a scenario, given their plans for the rapid development of new infrastructure – typically using carbon-intensive 'off-the-shelf' designs – and lower economic capacity to absorb such shocks.

While the considerations above are relevant to all developing economies, they present a particularly complex set of challenges for those with fossil fuel resources. These aspirations may seem theoretical and idealistic where a government's priority is to raise the country's standard of living through the provision of reliable power, infrastructure (access to economic markets) and fresh water supplies, but they are central to longer-term resilience throughout the transition. The extent to which it still makes sense to explore for and develop hydrocarbon reserves will depend on the type of oil or gas and its likely export markets, the scale of the resource and the cost of development, as well as its impact on land, water and other resources for socio-economic and environmental services.

[102] Such a transition would also include a reduction of 30 per cent in investment in fossil fuel energy, a 31 per cent rise in financing for core low-carbon infrastructure, and a 38 per cent increase in funding for energy efficiency. The Global Commission on the Economy and Climate (2017), *The Sustainable Infrastructure Imperative – Financing for Better Growth and Development, The 2016 New Climate Economy Report,* Washington, DC: The Global Commission on the Economy and Climate, p. 23, http://newclimateeconomy.report/2016/wp-content/uploads/sites/4/2014/08/NCE_2016Report.pdf (accessed 31 May 2018).

[103] UNECA (2017), 'Green approach to closing Africa's huge infrastructure gap has immense benefits, says ECA's Mofor', 23 October 2017, *United Nations Economic Commission for Africa*, https://www.uneca.org/stories/green-approach-closing-africa%E2%80%99s-huge-infrastructure-gap-has-immense-benefits-says-eca%E2%80%99s (accessed 31 May 2018). See also the extensive literature on 'greening industrialization'.

Carbon risks and their implications for country planning

In summary, the development of fossil fuels can result in linkages to the rest of the economy that heighten 'carbon risks' at the country level. The greater range of uncertainty around investment and revenues and the prospect of a declining export market is likely to change the value proposition for emerging and early-stage producers that have embarked on production or are considering expansion of the sector.

The scenario analysis reveals several issues that are likely to be of concern for producer countries:

- First, carbon constraints could radically reduce future net government revenues. The scenarios show a reduced budget for CO_2 in a world without widespread CCS application, which results in Ghana's oil revenues falling by 50 per cent and Tanzania's natural gas revenues dropping by up to 80 per cent. The potential range of revenues for gas is higher in the scenarios, given the sensitivity of gas to the application of CCS (for gas-fired power plants) and its much higher infrastructure and transportation costs. However, as noted in Chapter 2, this may be understating the potential for more disruptive shifts in oil demand.
- Second, rising domestic oil and gas demand is likely to exacerbate the fiscal stress of falling revenues, by either diverting potential exports to the domestic market (reducing foreign exchange inflows) or resulting in rising fossil fuel imports (increasing foreign exchange outflows). Ghana, for example, could become a net oil importer between 2025 and 2030 just as its oil revenues begin to fall; foreign exchange to cover import costs would have to come from other areas. Greening demand through energy efficiency measures and the uptake of clean energy systems can help reduce this stress, as well as supporting NDC implementation.
- Third, shifting fossil fuel demand and investment patterns may affect the overall time frame for diversification away from the fossil fuel sector. The scenarios call into question how long plateau production could be maintained, given the need to continually invest to extend the life of fossil fuel reserves. In the longer-term, re-investment in the sector and replacement of reserves will become increasingly challenging in a declining market, particularly where higher-cost, marginal production is concerned.
- Fourth, expectations for the role of fossil fuels in the economy over time appear high compared to the most carbon-constrained case scenarios. Countries are not typically planning for a 'worst case' scenario for fossil fuel demand – either in terms of lower than expected revenues, or delays or the failure to reach a final investment decision. These may also arise due to factors unrelated to decarbonization. Delays and sequencing problems typically affect energy security and lead to high-carbon and high-cost expensive fall-back options, with current account and emissions implications.
- Fifth, energy and industrial infrastructure choices and financing deserve greater attention at the outset of discussions around the development of expansion of the oil and gas sector, given that they will affect a country's energy and emissions pathway over decades, and thus its ability to deliver its long-term climate strategy and wider green growth goals. Domestic infrastructure choices should be considered in light of the full costs of a fossil fuel-led development pathway, and the co-benefits of a zero or low fossil fuel pathway – including reduced air pollution and water stress and investment in sustainable infrastructure and green sectors of the economy.

How might scenario analysis be useful?

Scenarios such as those conducted for Ghana and Tanzania can help plot the interaction of production, domestic consumption and revenues under different climate scenarios. Although beyond the scope of this paper, they would ideally be supplemented with implications for emissions and other quality of life indicators.

Such exercises could be used to bring together several areas of strategic planning in a country in order to 'carbon-stress test' national plans relating to revenue management, energy and industrial policy, and the fossil fuel sector itself. They could also help better decision-making in terms of whether to develop or expand the fossil fuel sector in the first instance, in light of alternative options for revenues, access to energy and economic growth.

Above all, the scenarios strongly suggest that developing countries expecting significant development gains from fossil fuel production urgently need new information, capacities and governance approaches that can challenge the short-termism of political cycles.

4. Building Carbon Resilience at Country Level

All countries need to adapt to carbon risk. As set out in Chapter 2, this is a rapidly evolving area for policy and finance in the advanced economies of the OECD, which is being driven in many cases by the investment and regulatory communities. To date, developing countries have had little engagement in this conversation. They are also likely to have lower institutional and technical capacities and fewer resources to develop carbon risk assessments and incorporate their findings into policymaking. Many will have limited capacity to plan for the long-term future, appraise investments and make sound cost-benefit analyses as they try to deliver basic services for their citizens. Some face severe capacity constraints due to conflict or endemic corruption.

In this chapter, we set out the considerations and policy areas for responding to challenges described in Chapter 3, bearing in mind that different countries will have different entry points into this process, and that success will depend on a government's willingness to engage on long-term issues, and on development assistance to address gaps in information and capacity. The stage of opening up or developing reserves matters in terms of what choices are on the table and where the focus should be.

Efforts to build resilience to carbon risks will stand the best chance of success if efforts are pursued through existing policy frameworks and framed by national priorities. For countries that are exploring for oil and gas and those that are about to begin or expand production, weighing up the trade-offs, opportunity costs and options for alternative development is critical. For those already producing, the role of revenues, the allocation of production, the ability to manage domestic demand and decarbonize the domestic energy mix, and the sustainability of infrastructure choices are all important tools for limiting exposure to carbon risk.

Drawing both on the findings of the scenario analyses in Chapter 3 and discussions with country stakeholders, there are three key areas for better information and capacity-building to emerge:

- 'Carbon competencies' in key areas of economic governance including revenue management and sustainable diversification.
- Energy and industrial policy that incentivizes the most energy-efficient and flexible technologies and systems and supports decarbonization over time.
- Preparing the fossil fuel sector for transition – setting the right agenda and incentives for its changing role over time.

Developing 'carbon competencies' in economic governance

For countries that have made the decision to explore for or develop reserves, effective management of the revenues and other payments associated with the fossil fuel sector is the first challenge. This means planning for the future and taking into account the potential delays in receiving any revenues – for example, a large-scale gas-to-power development may not deliver any significant returns for 10–15 years, given the fiscal terms agreed for companies (in terms of recouping their costs). During that time, public expenditure (including the payment of international debt) can become increasingly dependent on the sector, presenting obvious fiscal risks and creating a barrier to sustainable diversification and low-carbon transition. This raises two questions:

- How might a country begin to assess and prepare for the impacts that decarbonization might have on revenues and other income from the sector?
- How might a country allocate revenues in order to minimize their exposure to carbon risks, and support transition?

In order to address these questions, central economic governance institutions including central banks, ministries of finance and those managing sovereign wealth funds (SWFs) should incorporate carbon risks and transition strategies into their long-term outlooks and planning from the earliest possible opportunity. They could begin by studying the implications of carbon linkages on fiscal stability over time, including budgetary dependence, the current account impacts of rising fossil fuel demand and infrastructure investments, and the sustainability of external debt, in the 'worst-case' scenario for fossil fuel demand.

Revenue management

Revenue distribution is often a point of political contention. Fossil fuel revenues should not be classed as 'income' but as 'reshuffled' assets: cash assets in return for depleting below-ground assets. For fossil fuel development to be worthwhile, some revenues must be used to stimulate economic activity and/or investment that will sustain the economy beyond reserves depletion or a declining market price.[104] The shift to a decarbonized economy, and the narrowing window for wealth creation from the sector, increases the importance of effective revenue management, and accountability for the sector's impact. Existing guidelines for the saving and spending of revenues, both regularly through the national budget and ad hoc capital expenditure, may need revision in view of decarbonization trends.

Developing some level of national consensus over long-term economic priorities, alongside setting performance measures over time, would help to establish how spending is contributing to priority areas and demonstrating gains in diversification. In Ghana, there is interest in how to direct revenues so that they stimulate market growth in key employment-generating areas like agriculture and tourism, both of which can be well-aligned with a 'green growth' pathway. For example, investment in Ghana's agriculture might have eliminated the country's rising import bills for basic foodstuffs, such as rice, which can be grown domestically. Investment in energy efficiency and the RE sector is another, perhaps obvious growth area. According to one workshop participant, 'Given the existential threat faced by the fossil fuel industry, it would be wise to invest the proceeds in the alternative industries that are likely to replace fossil fuel as an energy source'.[105]

Well managed fossil fuel revenues could, in theory, provide a source of revenue for NDC implementation and support a wider 'green growth' strategy at home while production is exported. However, this conflicts with the traditional 'fossil fuel-led' development pathway, which emphasizes the development of linkages between the fossil fuel sector and fossil fuel-based value chains. It also assumes that revenues will flow in time to support transition, when in reality, governments often see little return from the sector until a decade or more after 'first oil'. Nonetheless, given the right context, growing carbon risks and the competitive advantages of a green growth pathway might make this an attractive option for some countries (see Box 6).

[104] Lahn and Stevens (2017), *The curse of the one-size-fits-all fix: Re-evaluating what we know about extractives and economic development*.
[105] Industry participant at the Accra workshop held in November 2017.

Box 6: Green growth and oil development in Guyana

At the Guyana National Seminar of the Chatham House New Petroleum Producers Discussion Group in June 2017, Minister of Natural Resources Raphael Trotman and Minister of Finance Winston Jordan both re-affirmed a national development vision for Guyana that was green and sustainable. The origins of this vision lie in Guyana's long history of forest conservation and its economy, which is driven by agriculture and mining, with some light manufacturing. Guyana has the world's second highest percentage of rainforest cover (85 per cent) and one of the lowest deforestation rates on Earth, making it a globally important carbon sink, storing some 5.31 gigatonnes of carbon.[106]

Guyana is also home to some of the world's largest oil discoveries of recent years. Since 2015, major oil discoveries by Exxon Mobil and partners have confirmed over 3 billion barrels of oil offshore, and this figure may still rise, with ongoing active exploration. Oil production is expected to begin in 2020. At the same time, Guyana currently relies on imported fossil fuels (largely from neighbouring Trinidad & Tobago) for most of its power generation. Electricity demand grew 18 per cent in 2010–15, despite the volatility of imported fuel prices and some of the highest retail electricity rates in Latin America and the Caribbean. Expectations of benefits from fossil fuel production are now growing among Guyana's small population of less than 800,000.

As President Granger put it, Guyana's vision is to develop 'a petroleum economy and a green economy, walking side by side, neither contradicting nor dominating one another'.[107] The key question is how oil development might influence Guyana's 'green' vision. Both its NDC and national development plan set out specific measures and a low-emission economic-development pathway to a 'green economy', including the target of developing a national energy system that is 100 per cent renewable by 2025 (supported by the country's ample wind, solar, biomass and hydropower resources), and commitments to mangrove restoration and avoiding deforestation. Delivering Guyana's 'green' vision will require careful assessment of the trade-offs associated with different energy and economic development pathways.

Oil revenues could, in theory, enable Guyana to fund many of the programs contained within its NDC and its wider green-growth agenda, including affordable access to energy. Guyana is planning to establish an SWF that will benefit future generations, as well as protect government spending against volatile commodity markets, and support spending to meet the country's urgent development priorities. Given its small population, geography and economic structure, Guyana could pursue an alternative development path to the traditional high-carbon industrialization model. In this context, 'greening' budgetary expenditure and the SWF may help enhance Guyana's management of carbon risks, while also delivering shorter-term clean energy and green growth goals.

At the same time, oil development has raised major infrastructure questions, including whether the development of joint refinery and industrial projects with neighbouring Suriname could boost economic activity, and whether the domestic use of associated gas for domestic power generation might be technically and economically feasible. However, unless carefully designed, the former risks locking-in high-carbon industrial activities, while the latter is incompatible with Guyana's ambition to use 100 per cent RE by 2025. However, acting upon robust analysis of the carbon risks and low-carbon opportunities associated with different energy and industrial pathways, particularly around revenue management and industrial infrastructure will demand strong political leadership.

Note: This box draws upon the Chatham House New Petroleum Producers Discussion Group Workshop '*Managing Resources Post-Discovery*', which was held in Georgetown, Guyana in June 2017. A wider workshop summary is available at: https://www.chathamhouse.org/sites/files/chathamhouse/publications/Meeting%20Summary%20-%20Managing%20Resources%20Post-Discovery.pdf.

[106] Guyana's Revised Intended Nationally Determined Contribution (2016), http://www4.unfccc.int/ndcregistry/PublishedDocuments/Guyana%20First/Guyana%27s%20revised%20NDC%20-%20Final.pdf (accessed 19 Jun. 2018).
[107] Foreign Affairs magazine (2018), 'Guyana: The Start of a New Era', January–February 2018, https://www.foreignaffairs.com/sites/default/files/guyana-country-focus-janfeb2018.pdf (accessed 31 May 2018).

Taxation and carbon pricing

Diversifying the economy based mainly on cheap inputs of domestic fuel is likely to result in fiscally unsustainable, high emitting industries. These can 'crowd out' other sectors and reduce productivity and competitiveness across the economy, including the areas where most citizens work, often agriculture. Surprisingly little of the literature on avoiding the resource curse and good governance has focused on getting the appropriate tax system for a country in place. Yet this is vital to supporting a diverse set of sustainable, competitive industries outside of the fossil fuel sector. Where revenue allocation is designed to promote other areas of the economy, this should be complimented by ongoing efforts to broaden the country's tax base and increase professionalism in this area.[108]

Ministries of finance, revenue authorities and other entities that shape fiscal policy will benefit from growing their competency in accounting for carbon.

Ministries of finance, revenue authorities and other entities that shape fiscal policy will therefore benefit from growing their competency in accounting for carbon. Donors and development financiers will increasingly apply a carbon price in screening projects for financing eligibility. In addition, a growing number of emerging economy governments are deploying carbon pricing instruments (taxation and other levies as well as trading), including large fossil fuels producers China, Colombia, Kazakhstan and Mexico, as a way to account for externalities, drive green growth and provide a source of additional revenue.[109] For a less developed country, this may begin with applying 'shadow pricing' to accounting, forecasting and performance indicators.

Building these capacities will not only help prepare for access to finance but also for potential application of carbon pricing mechanisms. Many existing measures in developing countries already implicitly put a price on carbon, e.g. duty taxes, fuel taxes, subsidies, feed-in tariffs and other green incentives. A 2017 Carbon Pricing Leadership Coalition meeting with sub-Saharan African countries, for example, highlighted how alignment of these with carbon pricing instruments could speed up NDC implementation but would require 'a good data basis and specific sector expertise to understand the dynamic interaction between carbon pricing and other green policies.'[110] Learning from other countries experimenting with tax, pricing and trading systems would help countries to find the best fit for their society.

Sovereign wealth funds

Many fossil fuel exporters have developed some form of SWF in order to insulate the economy from price volatility in the short-term and support future generations in the long-term.

Stabilization funds can help countries manage price volatility and declines. Recent experience suggests that developing producers with heavy dependence on a single export commodity and high levels of public expenditure and external debt have been quick to raid these funds during times of

[108] Fjeldstad, O., Jahari, C., Mmari, D. and Sjursen, I. H. (2016), *Non-resource taxation in a resource rich setting: A broader tax base will enhance tax compliance in Tanzania*, Repoa Brief no. 47, April 2016, http://www.repoa.or.tz/publications/category/briefs (accessed 31 May 2018).
[109] See, for example World Bank (2017), 'State and Trends in Carbon Pricing 2017', November 2017, pp. 13–14, https://openknowledge.worldbank.org/handle/10986/28510 (accessed 8 Jun. 2018).
[110] Carbon Pricing Leadership Coalition website (2017), 'Enabling Collaborative Action on Carbon Pricing in Africa', 31 October 2017, https://www.carbonpricingleadership.org/news/2017/10/27/enabling-collaborative-action-on-carbon-pricing-in-africa (accessed 21 Jun. 2018).

low prices (e.g. Nigeria's Excess Crude Account). Ghana's stabilization fund, although designed and implemented with the best technical advice and capacity-building, was not sufficient to cushion the 2015–16 drop in export revenues. In a cyclical market with booms and busts, well designed and well managed stabilization funds should be sustainable. However, in a declining market, repeated draw-downs may leave producers in an increasingly vulnerable fiscal position over the years.

Sovereign wealth fund investments in fossil fuel and other high-carbon assets effectively represent a 'double exposure' to carbon risk through a country's international investments.

The international investment of revenues also warrants attention, in light of wider divestment trends. SWF investments in fossil fuel and other high-carbon assets effectively represent a 'double exposure' to carbon risk through a country's international investments. For those starting out, there is an opportunity to follow the lead of the world's largest SWFs and pension funds from the outset. As set out in Chapter 2, many of these actors are now moving to divest from fossil fuels and diversify their portfolios. Effective management of carbon risk through the SWF requires effective partnerships between the leading institutions in-country – the central bank or ministry of finance, for instance – and where applicable, their international investment managers in order to develop and implement 'best in class' strategies for the sustainable investment of the SWF, including diversification and divestment from international assets that are at risk of losing value through the energy transition.

Countries should also consider the extent to which investments can help support domestic transition. In an era of low-interest rates, countries that have traditionally invested a percentage of their fossil fuel revenues in international markets are re-assessing their investment strategies. Some have questioned whether a different investment strategy – for example by investing at home in sustainable infrastructure or the protection of assets through forest conservation and afforestation – could deliver better returns in the long run. However, countries relying on raw materials export are often subject to volatile currency exchange rates meaning that keeping a reserve in a more stable currency can increase economic security.

Designing energy and industrial policy for transition

For some countries, oil and (more often) gas supplies may also be available to the domestic economy. Effective management of these fuel supplies and their role in the economy can reduce exposure to carbon risk and support decarbonization over time.

Countries need information and planning capacity ahead of that time, in order to head off unrealistic expectations. When fossil fuel resources are discovered, there is a tendency for politicians and industry alike to 'crowd around' the resource and compete for access to the perceived political or competitive advantages that rents and cheap inputs might confer. In the case of gas, national 'master plans' frequently highlight a role for gas across the domestic power sector and multiple industries, but rarely examine this against overall fossil fuel supply or the required investment. This 'supply-led' approach tends to result in over-inflated expectations of the role that fossil fuels can play in the economy and potentially detrimental competition between sectors for fuel (e.g. between power and industry).

Moreover, the 'competitive advantage' that the use of domestically produced fuels might confer is changing rapidly with the diversification of the global economy. Developing the value chain domestically and building economic linkages with the rest of the economy (mainly through power and energy intensive industry) has become part of the received wisdom for producers since at least the 1970s. However, the countries that have made a success of this, such as the Gulf Cooperation Council countries and Trinidad and Tobago,[111] are now facing challenges with respect to sustainable diversification and job creation mean a reassessment of this model is needed.

This raises two important questions for country decision-makers:

- First, to what extent does encouraging energy and industrial linkages with the rest of the economy make sense in the context of reserves, capacity to spend revenues and the changing picture of competitiveness in a decarbonizing economy?
- Second, whether the use of fossil fuels in domestic power systems and industrial activities supports or undermines a country's NDC and long-term emissions reduction plans to 2050 under the Paris Agreement and, in turn, the finance and technologies required for their delivery.

As discussed in Chapter 3, energy and industrial policy and national development plans have a major role to play in shaping these two dynamics.

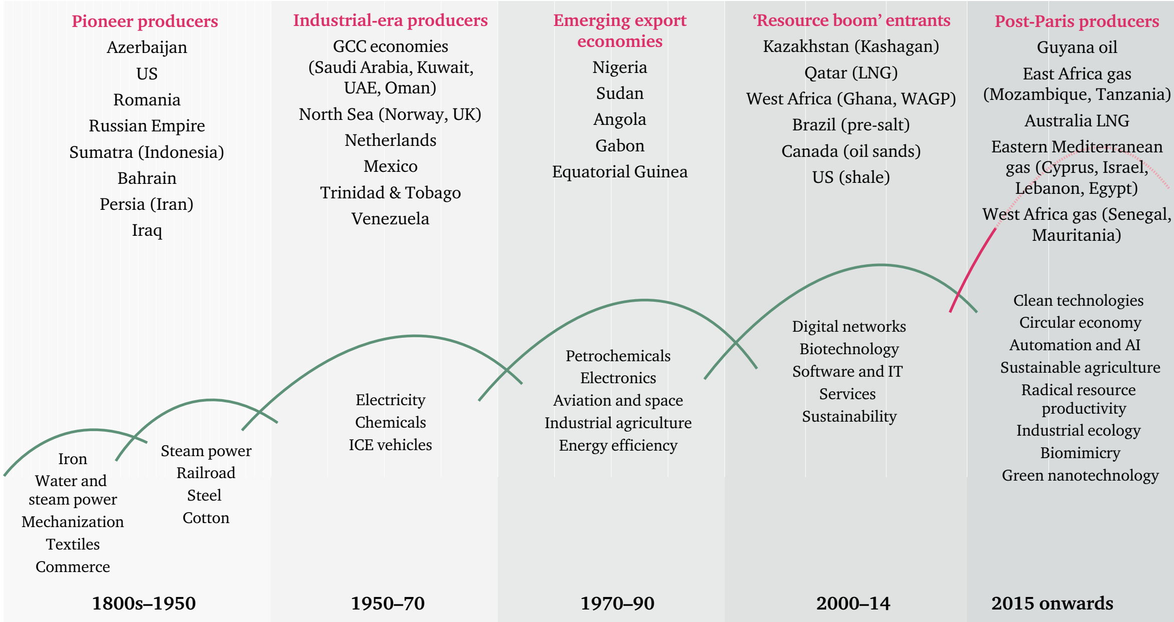
Interrogating the viability of energy-intensive industrial plans

The continued viability of fossil fuel-led industrial plans warrants greater scrutiny. Industrial innovation comes in waves, shaped by wider macroeconomic trends. Figure 13 shows the emergence of new oil and gas producers on each wave of innovation and global structural transformation. Emerging producers may have an opportunity to leapfrog traditional industrial value chains, and avoid the development of high-carbon industries that entail exposure to carbon risk, as well as 'crowding out' agriculture, light manufacturing, services and other industries that can support sustainable economic diversification. Greening industrialization and ensuring compatibility with long-term 2050 plans can also help avoid the need for expensive retrofitting or the retirement of carbon intensive infrastructure down the line.

In the case of Ghana, despite initial optimism, gas-based industries do not appear prudent given the scale of the resource or the time frame for production. While a number of government and industry leaders interviewed in Ghana, in late 2016, expressed hope that gas would be used in power (including exports to regional neighbours), petrochemicals, fertilizers and transportation,[112] the updated Gas Master Plan (GMP) of 2016 is more measured in its expectations for gas use in the domestic economy. Ghana's Ministry of Energy estimates that gas-based industries might be commercially viable within a gas price range of \$9–\$12/MMBtu, effectively ruling out the use of domestic gas in urea, steel and aluminium industries, and casting doubt on its prospects for use in methanol and transport.

[111] For more explanation of industrial gas development and current issues facing Trinidad and Tobago, see Lahn and Bradley (2016), *Left Stranded? Extractives-led Growth in a Carbon-Constrained World*, pp. 18–19.
[112] For example, a Ghana Export Promotion Council webpage from 2010 is telling in that it seems to promise fuel for industry, electricity, transport and exports of natural gas: 'Ghana can stop using liquid fuels in industry and power generation… The people can look forward to reduced electricity bills and lower fuel costs for their vehicles… The export of natural gas from Ghana will open up a whole new revenue stream for the country', Ghana Export Promotion Council (2010), 'Ghanaian Natural Gas – A Huge Asset', http://www.gepcghana.com/naturalgas.php (accessed 30 May 2018).

Figure 13: Energy producers through two centuries of industrial innovation and structural transformation



Source: Chatham House, drawing on UNECA (2016).

By contrast, Tanzania maintains ambitious plans for the development of heavy industry fuelled by domestic gas (and coal). The expectation is that electricity will account for the bulk of fuel demand in the short-term and that nascent industrial sectors – including steel, cement, chemical fertilizer and petrochemical industries – will be supplied by the surplus. Politically, these industries appear attractive; steel industries could add value to domestic iron ore and coal production, and supply emerging urban national and regional demand centres, while the development of a fertilizer industry could create linkages to the agricultural sector, and enhance its productivity and employment prospects. This is dependent on a final investment decision from their international investors, and a range of factors including domestic fuel pricing and export potential in a market where established lower cost producers have a surplus (e.g. Chinese steel, Gulf and Chinese petrochemicals).[113]

Integrated upstream, energy and climate planning

While it is hard to imagine any way in which developing domestic coal supply could contribute to NDC goals, there are, in theory, ways that the oil and gas sectors could play a role. For example, there may be opportunities for domestic gas production – and liquid petroleum gas (LPG) processed from gas or crude oil – to displace higher-carbon or more environmentally-damaging energy practices, namely coal for heat and power and biomass for cooking. Where there is 'associated gas' from existing oil production, utilization may also present an opportunity to eliminate flaring.

The utilization of fossil fuels in the domestic market carries significant costs. Natural gas discoveries may require prohibitive capital outlays and intensive policy efforts, particularly where there are no associated oil exports to help guarantee a government's ability to finance the initial capital

[113] UNECA (2017), *Greening Africa's Industrialization – Economic Report on Africa*, UNECA: Addis Ababa, http://www.un.org/en/africa/osaa/pdf/pubs/2016era-uneca.pdf (accessed 30 May 2018).

expenditure required in domestic gas-fired generation and grid infrastructure, and the operating expenditure to pay for gas supplies. Most developing countries require large-scale development assistance in order to access the foreign capital and technical expertise required to implement and operate such gas projects. In the case of cooking fuel, key considerations include the extent to which the government should subsidize gas prices to reduce deforestation, and the necessary reforms to sector regulation and the wider business environment that would be required in order to support the effective marketing of LPG as an alternative to firewood or charcoal (see Box 7).

Box 7: What would it take to displace wood fuel with LPG?

Many countries shown in Figure 1 are suffering from high rates of deforestation. Most of their NDCs emphasize forest preservation and afforestation as a contribution to climate change mitigation in terms of reducing emissions from land-use change and providing 'carbon sinks'. Thus, there is strong interest from emerging fossil fuel producers in how LPG and natural gas might displace wood and charcoal use in cooking, which is a contributor to deforestation.

Since at least the 1980s, the transition in cooking practices from basic fuels to more advanced and cleaner methods has been perceived as a move up the 'energy ladder'.[114] This is usually understood as households moving from dung and waste to firewood to charcoal to kerosene to LPG/biofuel, and finally, to electricity. To date this movement has been slow; the global SDGs and the Sustainable Energy for All (SEforAll) initiative are promoting a much faster transition from biomass to 'tier 3' fuels (LPG or second-generation biofuels), as this change promotes access to energy, health, and forest conservation benefits.

The use of LPG – propane, butane or a mix of the two that must be refined from crude oil liquids or natural gas – has taken off in countries across western Asia and parts of Southeast Asia and South America, which used to be dependent on biomass. It also holds promise as an alternative to wood and charcoal use in both Ghana and Tanzania, if infrastructure and pricing can stimulate demand. Like most countries where the majority of cooking uses biomass, both Ghana and Tanzania have a history of shortages and disruptions in LPG supply, as well as poor investment in infrastructure, packaging and safety, despite efforts to encourage LPG through subsidization. Problems include both limited availability of LPG to private sector retailers, and a lack of standardization and regulation.

For an LPG market to succeed and displace other fuels, a number of barriers must be addressed. The relative price of current fuels and LPG is critical, but there are other considerations. Many of the cooking fuels used among the poorest communities are collected biomass, which may not incur a monetary cost, but are time consuming to collect – mainly for women and girls. Therefore, stimulating LPG demand may require a broader approach.[115] There are often cultural preferences for cooking with wood or charcoal, but equally there may be social incentives for switching, including cleaner living areas, less time spent collecting wood and clearing away soot, and the status associated with having a gas stove; all of which need to be recognized in any large-scale plan for LPG. Enabling the adoption and use of LPG stoves is critical in supporting long-term LPG use.[116]

There are also various critiques of the energy ladder hypothesis that deserve attention. Several studies have found that households will rarely make a complete shift from wood fuel to LPG and transitions may not be linear. Instead, LPG adoption often has a strong correlation to other socio-economic improvements and associated household upgrades, as well as changes in community conditions, such as improved road access.[117]

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[114] Dowd, J. (1989), *The urban energy transition and interfuel substitution in developing countries: a review of the literature*, Internal Report, ESMAP, Washington, DC: World Bank.
[115] Kumar, P., Dhand, A., Tabak, R. G., Brownson, R. C., and Yadama, G. N. (2017), 'Adoption and sustained use of cleaner cooking fuels in rural India: a case control study protocol to understand household, network, and organizational drivers', *Arch Public Health,* 75:70. doi: 10.1186/s13690-017-0244-2, https://www.ncbi.nlm.nih.gov/pubmed/29255604 (accessed 31 May 2018).
[116] Alem, Y., Ruhinduka, R., Berck, P., and Bluffstone, R. (2015), *Credit, LPG Stove Adoption and Charcoal Consumption: Evidence from a Randomised C ontrolled Trial*, Working Paper, London: International Growth Centre, https://assets.publishing.service.gov.uk/media/57a08991e5274a27b2000147/89225_final_report_ARBB2015-V5.pdf (accessed 30 May 2018).
[117] Masera, O., Saatkamp, B. D., Kammen, D. (2000), *From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model*, World Development, 28(12), pp. 2083–2103, https://pdfs.semanticscholar.org/4cae/b11ee48549a534e94edc0241d5d87f30b5cf.pdf (accessed 30 May 2018).

There is clearly the need for change in cooking practices in many countries that need to reduce deforestation. The use of domestic natural gas or oil as a cooking fuel is worthy of attention as an SDG enabler, and where wood fuel for cooking is a major challenge to forests, as an NDC enabler. But it must take into account the trajectory of natural gas/crude oil condensate availability, the timing and expense involved in domestic processing, and the likelihood of a return to imports after a period of self-sufficiency. At the same time, LPG may face competition from advances in solar cooking technologies that may result in their wider use alongside other cooking fuels and sustainably managed forests.[118]

A successful programme to transform practices must therefore consider and be prepared to finance a long-term, holistic approach. There should be no illusions as to the costs, times and effort involved. Multiple government agencies and the fossil fuel industry need to coordinate; initial investment must be ploughed into the distribution infrastructure and in getting the right cooking equipment to markets. Furthermore, culturally-appropriate awareness and training are needed at the local level to foster demand and ensure safety.

Gas should not necessarily be considered a 'transition fuel' in the switch to a low-carbon economy. Plans for the domestic use of natural gas need to be carefully interrogated in view of infrastructure costs, fuel prices, electricity tariffs and the capacity of the main off-takers to pay for the product – all of which present major challenges to the power sector in a less developed country context. They also need to be considered in light of technological advances and falling costs in energy storage; in Australia, for example, Tesla's deployment of a 100MW battery has helped overcome gas power outages and price spikes.[119] The company is also developing the capacity for 'virtual power plants' in post-hurricane Puerto Rico, Australia and Lebanon, with the installation of batteries in networks of up to 50,000 homes.[120] Meanwhile, the rationale behind the use of gas as a balancing fuel for intermittent RE is questionable amid the wider shift from rigid baseload power to more flexible systems of energy delivery.[121] In terms of emissions comparisons, methane leakage from gas projects must be also taken into account when considering the merits of gas as a 'lower carbon' transition fuel.[122]

Box 8 gives some of the key considerations and capacities for guiding the use of natural gas – and other fuels – in the domestic economy with reference to the experience and ambitions in Ghana and Tanzania.

[118] Little research has tracked long-term use of solar cook stoves. This page gives some international project and business examples: Solar Cookers International (last updated February 2016), 'Most significant solar cooking projects', http://solarcooking.wikia.com/wiki/Most_significant_solar_cooking_projects (accessed 30 May 2018).

[119] Australian Associated Press (2017), *South Australia turns on Tesla's 100MW battery: 'History in the making'*, The Guardian, 1 December, https://www.theguardian.com/australia-news/2017/dec/01/south-australia-turns-on-teslas-100mw-battery-history-in-the-making (accessed 19 Jun. 2018).

[120] See, for example, Lambert, F. (2018), *Tesla has 'about 11,000' energy storage projects underway in Puerto Rico, says Elon Musk* Electreck, 3 June, https://electrek.co/2018/06/03/tesla-energy-storage-projects-puerto-rico-elon-musk/ (accessed on 19 Jun. 2018); Lambert, F. (2018), *Tesla to supply another 'virtual power plant' with Powerwalls at up to 1,200 homes*, Electreck, 28 March, https://electrek.co/2018/03/28/tesla-powerwall-virtual-power-plant/ (accessed 19 Jun. 2018).

[121] See, for example, Dyson, M. (2017), *Who needs 'baseload' power? (Or, let the markets do their job)*, GreenbizMedia, 26 June, https://www.greenbiz.com/article/who-needs-baseload-power-or-let-markets-do-their-job (accessed19 Jun. 2018); Steinberger, K. and Farmer, M. (2017), *Debunking Three Myths About 'Baseload'*, NRDC Expert Blog, https://www.nrdc.org/experts/kevin-steinberger/debunking-three-myths-about-baseload (accessed 19 Jun. 2018).

[122] Shearer, C. et al. (2014), 'The effect of natural gas supply on US renewable energy and CO_2 emissions', *Environmental Research Letters*, 9(9), http://iopscience.iop.org/article/10.1088/1748-9326/9/9/094008/meta (accessed 2 May 2018).

Box 8: Key considerations for guiding the use of gas

Given the experiences and plans for development in Ghana and Tanzania, several considerations and competencies stand out as essential for making decisions about the gas sector and guiding the use of gas and other fuels in the domestic economy:

Infrastructure costs: A full understanding of the costs, timing and sequencing of putting in place measures for capture and utilization of associated gas is critical for effective decision-making. When gas is not delivered on time, it may lead to higher costs and higher emissions from emergency measures, such as power barges or increased fuel imports, as seen in Ghana. As Ghana's Gas Master Plan (GMP) acknowledges, it is 'faced with substantial challenges in the provision of new infrastructure in the coming years and is therefore unlikely to be able to meet all investments required under the GMP'.[123] Tanzania's 2016–45 Natural Gas Utilization Master Plan (NGUMP) is far more aspirational – its NGUMP projections for gas use are difficult to envisage, given the capital required for the necessary power, industrial and transportation infrastructure. It is currently being revised.

Fuel pricing: The pricing of fuel is a critical factor in domestic energy consumption and the transition to a diversified, low-carbon economy. To incentivize low-carbon pathways, where fuel substitution is considered, the consumer price of an alternative fuel has to be high enough to make investment in infrastructure and processing commercially feasible, yet low enough to ensure it is used instead of less efficient fuels, such as diesel, wood, charcoal and coal. Unlike oil, natural gas requires extensive infrastructure (processing, pipelines, gas turbines, city gas networks, compressed natural gas (CNG) stations etc.) in order to create demand. The international price plus transportation cost may not be appropriate as a reference price for domestic sales of gas, given the investment needs of domestic gas infrastructure, local costs of production and the relative value of this sector to national industrialization, poverty alleviation, and energy access objectives.[124] It is important that countries have access to the full costs of production (including emissions, water demand and depletion costs). The ability to 'price in' carbon (as mentioned earlier) and other emissions will be useful in this regard, even if the full cost is not immediately applied to the domestic fuel price.

Electricity tariffs: The level of electricity tariffs can have an impact on consumer fuel choices. This was demonstrated in Ghana in 2016 when electricity tariff reforms were introduced. These reforms were generally considered 'a step in the right direction' by government technocrats; however, they were not without controversy, and were considered a 'step too far' by others. Larger consumers such as hotels and factories responded perversely to the tariff reforms by using their allocated lower tariff blocks from the grid and then switching to their own diesel generators, which were less expensive per kilowatt hour (kWh) than the higher tariff blocks. As a result, demand for power through the national grid was said to have fallen by 25 per cent, causing further revenue generation problems for suppliers.[125] In 2018, the government partially reversed the tariff reforms to address these misaligned incentives.

In addition to costs arising from distribution losses and other inefficiencies, and the inflated costs of new power plants (ostensibly due to uncompetitive practices), the inflated costs of new thermal power plants, ostensibly due to uncompetitive practices, also contribute to high systems costs. According to one workshop participant, 'It should have cost $120 million for a 100MW plant but [the government] has paid twice that, and now the consumer is paying for that'.[126]

[123] Republic of Ghana (2016), *Natural Gas Plan*, http://energymin.gov.gh/sites/default/files/06-14%20GMP%20Updated.pdf (accessed 31 May 2018).
[124] For more in-depth considerations for gas pricing, see Lahn, G. and Stevens, P. (2014), *Finding the Right Price for Exhaustible Resources: The Case of Gas in the Gulf*, Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/sites/files/chathamhouse/field/field_document/20141017LahnStevensGas.pdf (accessed 20 Apr. 2018).
[125] Interview with the authors, Accra, October 2016.
[126] Interview with the authors, Accra, October 2016.

Energy policy levers

The scenarios in Chapter 3 highlight the importance of a country maintaining export flexibility by steering domestic energy demand away from dependence on domestic fossil fuel supply. Once dependent on fuel supplies, domestic energy demand growth can compound current account stress in a number of ways. Energy policy can deploy several levers to ensure fuel is efficiently allocated, and incentivize transition over time including target setting, establishing the right price regimes to incentivizing cleaner, more efficient practices, and gradually taxing higher-emissions fuels and using the revenues to invest in low-carbon public goods, such as mass transit systems. In particular, demand-side interventions, including exploiting the most efficient and cost-effective technologies and systems can help reduce current account stress, enhance energy security and support NDC implementation.

Empowering an independent regulator

Regulators and planners tend to express strong interest in keeping up with rapidly shifting technological advances, pricing and business models, which will affect the competitiveness of different energy sources and technologies over time. This area is rich for discussions at the outset of plans to develop or expand fossil fuel production to ensure that there is sufficient emphasis on energy policy and integration with sustainable energy goals. A professional, independent electricity or energy regulator has been critical in several fossil fuels exporting countries (Oman, Saudi Arabia, South Africa, UAE) in driving programmes to increase power and water efficiencies to rein in the waste of fuel.[127] It can also help create an investment infrastructure and operating environment to take advantage of new practices and technologies and scale the use of RE over time. If one does not already exist, at least as much effort should be directed into developing this institution at the outset of a discovery as goes into developing an NOC.

Shaping the peak in energy demand

A greater focus on demand can help shift the emphasis of energy discussions in fossil-fuel producing countries from a supply-led approach to a demand-led energy services perspective. Energy policy and investments should prioritize the end goal, e.g. reliable and affordable access to clean energy services, rather than the means, e.g. development of the fossil fuel sector. This may provide something of a counterbalance to the political economy and 'path dependency' that tends to emerge around the development of a fossil fuel sector.

There are also great opportunities to scale up energy efficiency, RE systems and sustainable infrastructure where a pipeline of 'bankable' projects can be developed, and where the right combination of climate or concessional finance, green finance and other support can be secured. Those countries with the most stable and competitive regulatory and legal frameworks governing investment in the power sector and infrastructure will be best placed to attract such investment as the experiences of RE in South Africa and Uganda demonstrate.[128] With a demand-side focus, understanding the end consumer of power becomes key. The planned roll out of electricity metering in Nigeria, for example, is expected to increase utilities revenues and thus enable needed investment as well as increase investor confidence in solar power.[129]

[127] Lahn, G. (2016), *Fuel, Food and Utilities Price Reforms in the GCC: A Wake-up Call for Business*, Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/publication/fuel-food-and-utilities-price-reforms-gcc-business (accessed 21 Jun. 2018).
[128] Montmasson-Clair, G. and Ryan, G. (2014), 'Lessons from South Africa's Renewable Energy Regulatory and Procurement Experience', *Journal of Economic and Financial Sciences*, September 2014, 7(S), pp. 507–526; Whitley, S. and Tumushabe, G. (2014), *Mapping current incentives and investment in Uganda's energy sector: Lessons for private climate finance*, Overseas Development Institute, https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8891.pdf (accessed 30 Jun. 2018).
[129] ESI Africa (2018), 'Nigeria: Electricity tariffs correlate with metering of consumers', 11 January 2018, https://www.esi-africa.com/nigeria-electricity-tariffs-metering/ (accessed 30 Jun. 2018).

Looking ahead, urbanization and industrialization trends can be exploited as an entry point to help 'shape' future energy demand, through smart urban planning and the procurement of the most efficient, low-carbon designs and materials. Such structural shifts, for instance the rural–urban spread of population and the rate of urbanization over time, will be important in decisions on expansion of grid power, and whether gas could effectively displace wood and charcoal use, for instance. The procurement, financing and delivery of sustainable urban and industrial energy systems and related infrastructure are key areas, and are rich for South–South learning, facilitated by MDBs and donors.

Defining an appropriate role for the fossil fuel sector

The institutions that manage and operate in the fossil fuel sector, including the ministry of petroleum, the upstream regulator, the SWF and the NOC, can all develop in ways that either help or hinder carbon risk management and green growth. As set out in chapters 2 and 3, while the overall implications of the global carbon budget suggest less investment in fossil fuels, the prospects of different fuels varies depending on their specific carbon intensity factors.[130]

> Almost all major IOCs are considering how to extend their profitable lifetime and find competitive advantages, as demand for their current primary products declines.

Almost all major IOCs are considering how to extend their profitable lifetime and find competitive advantages, as demand for their current primary products declines. In contrast to IOCs, where strategy is influenced by the need to return fairly short-term dividends to shareholders, NOCs have a special role as the government is its only or largest shareholder and they are usually established with a mandate to serve national interests. For these reasons, NOCs should experience less conflict of interest in planning for transition. In reality, NOCs often develop without much connection to other national goals and processes, and are sometimes captured by a group of elite interests. They often have ambitious growth targets, including taking a greater share of (carried) equity in projects, and even developing operational competencies.

This raises important questions about how, from the outset, the right incentives can be set, and the right capacities and interlinkages built, to ensure that state entities are able to concentrate on their core task, while avoiding exposure to carbon risk and supporting transition.

Limiting exposure to upstream risk

This paper sets out a number of uncertainties that decarbonization trends present for national governments. Actors in the upstream fossil fuel sector are used to dealing with risk.[131] These risks fall broadly under three categories: the risk associated with exploration, i.e. that drilling fails to make a commercial discovery, and therefore generate a return ('prospect' risk);[132] the risks associated with upstream contracts (contract risk);[133] and, the risk that changes in the project (operating costs,

[130] Carnegie Endowment for International Peace (2015), 'Oil-Climate Index', http://oci.carnegieendowment.org/ (accessed 30 May 2018).
[131] Risks are measurable, uncertainties are not.
[132] The probability of this risk can be calculated, based on a project's geology and other characteristics.
[133] This changes over time; obsolescing bargain theory suggests that bargaining power typically shifts from the operator to the government once there is a discovery.

accidents) or international context (demand, prices) affect the development of a discovery or the returns of a producing asset (commercial risk).

Governments are exposed to some level of risk through their share of revenues or through the changing prospects for exploration or development where there are proven reserves. In general, upstream contracts have developed over the past few decades, so as much risk sits with the operator and away from the state. They are typically structured so that exploration costs are borne by a company, as are the costs and risk of development, if there is a discovery.

Disruptive shifts in international prices may affect the perceived 'fairness' of contracts, raising the prospect of parties reneging on sales (off-take) contracts, for instance; although this risk tends to sit with the operator.[134]

The establishment and mandate for an NOC should therefore be re-considered in light of growing carbon constraints, and wider national development goals. This could include a role concerned with maximizing the value of fossil fuel assets to the country, but also with optimizing their role over time. The distribution of risk between the state (and public finance) and the private sector should be carefully considered, where re-investing in the upstream and developing operational competencies are concerned. For example, where the government share of revenues is delayed until after the private investor has recouped their capital, this may effectively increase the costs and reduce the returns of governments.

Building capacities for transition

Many established NOCs are now re-considering their long-term commercial strategy and national mandate, in light of the decarbonization trends. Evolution of the NOC as a 'manager of carbon' may be an appropriate role for some. This includes developing the skills to understand consumer preferences in their export markets, and shifting international investment patterns. Pursuing a long-term transition from an NOC to an 'NEC' (national energy company) may be an attractive proposition for others. Just as many IOCs are attempting to build their RE and clean technology investments and capacities, so too are established NOCs such as Saudi Aramco. However, such strategies should be underpinned by a robust national conversation about the most appropriate institutions and processes to promote the integration and scale-up of RE and other clean technologies.

Building capacity within the ministry, regulator or NOC represents a first step towards managing emissions (including methane) and carbon risk. Some competencies, such as reducing the life-cycle emissions of their products, and the monitoring and enforcement of efficiency and RE standards in the sector will likely be owned by the leading institutions in that area. Others, such as the application of shadow carbon pricing, will have relevance across the energy system and wider economy, applying to both upstream decision-making and (where production is to be allocated to domestic market) power sector stakeholders and national planners, among others. The associated skill sets are also likely to be in increasing demand across the domestic economy and internationally (as mentioned earlier).

[134] This may be an issue for upstream contracts, and for sales contacts (typically made between the operator and the buyer). State and private-sector operators are well-versed in these dynamics, following the resurgence of 'resource-nationalism' in the late 2000s. See, Stevens, P. et al. (2013) *Conflict and Coexistence in the Extractive Industries*, Chatham House Report, London: Royal Institute of International Affairs, https://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy%2C%20Environment%20and%20Development/chr_coc1113.pdf (accessed 31 May 2018).

Using NOC and government licensing and procurement power to stimulate the domestic market in low-carbon products and services is another area for consideration. The fossil fuel industry is usually a significant energy consumer. Particularly where there are local content measures, where competitive, how could it promote energy efficiency services and the deployment of RE technologies within the sector, and set procurement standards for sustainable infrastructure that take into account long-term emissions reductions? Other considerations involve industry-related infrastructure, the procurement and deployment of which can contribute to green growth sectors of the economy.

Peer-to-peer networks with more established NOCs such as those in the Gulf and East Asia can help accelerate learning at the technical and policy and strategic level. MDBs, donors and other development advisers to the sector have a role to play in facilitating such platforms.

5. Aligning International Development Assistance

All MDBs and donor countries are committed to the long-term goal of the Paris Agreement, and have rapidly scaled up their climate finance commitments in the last decade. Reforming development assistance to the fossil fuel sector to ensure its alignment with these commitments has proved more difficult, given the potential for fossil fuel production to support some key development goals. At the same time, support to the sector tends to have disproportionate political influence in developing countries and may therefore be a priority area where requests for international assistance are concerned. This means that financing and support for green growth and lower-carbon pathways needs to engage with the challenges that developing countries with fossil fuels face. Deploying climate finance effectively in these contexts will require understanding of politically viable alternative development models or support for transition that accounts for existing fossil fuel interests and exposure to carbon risks.

Aligning finance and assistance with climate commitments

The first question for donors and MDBs is whether and how international support for fossil fuel sectors can be made consistent with the carbon budget necessary to meet the 'well below 2°C' target. The potential conflict between support to the fossil fuel sector and climate considerations was raised as early as 2004, in the World Bank's extensive Extractives Industries Review.[135] Yet until recently, MDBs and donor countries had rolled out inconsistent messages on fossil fuels, which reflected inconsistencies and internal differences at home regarding what they should support internationally. The result was generally a withdrawal from coal, growing support for gas as a 'bridge' to a lower-carbon future, and ambiguity where oil was concerned.

Only now are MDBs and donors beginning to make meaningful reforms to the ways in which they assist the fossil fuel driven economies (see Annex I for selected case studies). Most are in the process of revising their energy and mining policies in order to better align them with climate commitments. The World Bank Group's decision in late 2017 to stop financing upstream oil and gas and apply 'shadow pricing' across its investments – including thermal power generation – marked a turning point in this respect, and has the potential to re-invigorate discussion around whether MDBs and donors should still be supporting fossil fuel development, and if so, under which circumstances this can be justified.[136] The EBRD's decision to support the TCFD process in early 2018 represents another important step towards the mainstreaming of carbon risk in development assistance.[137]

[135] World Bank (2004), *Striking a better balance: the World Bank Group and extractive industries – the final report of the extractive industries review*, Washington, DC: World Bank, http://documents.worldbank.org/curated/en/961241468781797388/Striking-a-better-balance-the-World-Bank-Group-and-extractive-industries-the-final-report-of-the-extractive-industries-review (accessed 31 May 2018).
[136] Bradley, S. and Lahn, G. (2017), 'The World Bank Won't Back Oil and Gas – What Now?', Chatham House Expert Comment, 18 December 2017, https://www.chathamhouse.org/expert/comment/world-bank-wont-back-oil-and-gas-what-now (accessed 31 May 2018).
[137] EBRD (2018), EBRD joins major initiative to promote financial stability in the face of climate change uncertainty, March 2018, http://www.ebrd.com/cs/Satellite?c=Content&cid=1395274336038&d=Mobile&pagename=EBRD%2FContent%2FContentLayout (accessed 31 May 2018).

For these reforms to be effective, it is critical that they are aligned with country priorities, including NDC and long-term emissions reduction plans to 2050. One area worth exploring is whether MDBs could screen investments for compatibility with the potential recipient country's plans and targets as outlined in their NDCs, while allowing scope for rising ambition to 2050. This should include assessments of implied emissions pathways and the potential for investments to support low-carbon goals, such as encouraging the role of gas or LPG in displacing higher carbon fuels and increasing energy access. However, this must be supplemented with a clear and full assessment of the systems costs through integrated energy planning of the sort outlined in Chapter 4, as well as the market requirements to enable this, and the level and coordination of development assistance that would be required. There are already some efforts in this direction; while they have little engagement in fossil fuels related activity, the French development agency (AFD) stated in 2017 that all its activities will be 'Paris-compliant', with an emphasis on avoiding the lock-in of unsustainable industrial dependencies that will place countries at a disadvantage in a 'well below 2°C world'.[138]

Is there room for 'fairness' in stranding?

At the same time, it is important that policy discussions and practical approaches to carbon risk and the need for transition are grounded in developing-country perspectives of fairness. Development assistance to fossil fuels has typically avoided engagement with the decision to explore or develop resources. All countries consider the decision to explore for and extract resources as 'sovereign'; indeed, this sovereign right to leverage natural resources is enshrined within the founding documents of the UNFCCC.[139] Low-income countries also rightly view their historical contribution to emissions as negligible, and addressing the issue of 'equity' has been critical to recent progress in climate negotiations.

Many decision-makers and civil society actors in developing countries view oil and gas resources as assets, and development of them as an opportunity to drive economic development. For these actors, there is the perception of an 'opportunity cost' associated with the stranding of fossil fuel resources. This sits uncomfortably with a 2°C global carbon budget, which implies that not all oil and gas reserves can be developed. As development agencies and MDBs reform their policy positions on fossil fuels, it will be hard to avoid the question of whether there is scope for 'fairness' in the way fossil fuel resources are 'stranded'. Better understanding of the economic implications of a 'fairer' approach may help MDBs and donors in their conversations with country decision-makers (Box 9).

New research on the distribution of unburnable carbon could also usefully inform a number of policy areas that fall within the sphere of influence of individual donors or 'coalitions of the willing'. For example, the reallocation of production implies give and take at the international level, with high-income producers constraining production in order to provide 'space' for lower-income producers. If Norway or the UK support overseas oil production in developing countries, should they concurrently reduce their own oil and gas production? Acknowledging the issue of 'fairness' through other policy levers – such as the removal of upstream subsidies, for instance – could help support a 'level playing field' for remaining fossil fuel production, as well as supporting the managed decline of less economic fossil fuel supply.

[138] This involves an evolving process of screening that began to be rolled out in 2018. Agence Française de Développement (2017), Climate & Development Strategy 2017–2022, https://www.afd.fr/en/climate-development-strategy-2017-2022 (accessed 10 Dec. 2017).
[139] Page 1 of the *United Nations Framework Convention on Climate Change (UNFCCC)* recalls that 'States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies'. See https://unfccc.int/resource/docs/convkp/conveng.pdf (accessed 19 Jun. 2018).

Box 9: A 'Development First' approach to future fossil fuel production

Previous attempts to estimate the remaining 'burnable carbon' budget by region, as originally modelled by Ekins and McGlade, have done so on the basis of least-cost production and transport, and have not considered equity.[140] At the same time, there is a growing body of literature that examines the relevance of equity for policy decisions relating to future fossil fuel supply.[141] Setting aside the political feasibility and the risks of any such approach, there is value in understanding whether there is any economic argument for redistribution. Who would be the winners and losers under any reallocation of production rights? Would any form of strategic 'allocation' make economic sense given the costs of production?

This box presents a reworking of the geographical distribution of unburnable carbon under a 'development first' scenario, which accounts for equity by allocating greater fossil fuel production rights to less developed countries. The global-level modelling uses the TIAM-UCL model and applies a UNDP Human Development Index (HDI) ranking to each of its regions to determine 'priority' levels (see Table 3) for allocating production levels. This draws upon the first of the three criteria proposed by Caney[142] for informing the integration of equity considerations into the hypothetical allocation of 'extractive rights':

- Development status/need for development – the strong need for economic development might mean that priority would be given to the least developed countries;
- Historical responsibility, or benefits accrued – a country that has already benefited vastly from fossil fuel extraction, might see its level of priority for continued extraction lowered; and,
- Alternative means of development – the availability of other (energy and income) options for development beyond extractives might effectively lower a country's level of priority.

Table 3: Allocation of TIAM-UCL regions to HDI groups

HDI group	HDI level (0–1)	TIAM-UCL regions
Low-medium	<0.7	Africa, India, Other Developing Asia
High	0.7–0.8	Middle East, Mexico, South and Central America, China, Former Soviet Union
Very high	>0.8	Western Europe, Eastern Europe, UK, Canada, USA, Australia, Japan, South Korea

Source: Compiled by UCL (2018), based on TIAM-UCL regions and UNDP HDI rankings.

The model allocates production 'quotas' to each HDI group, determined by the application of an HDI-differentiated carbon tax on production (a full methodology is provided in Annex II). The resulting redistribution of oil and natural gas production can be seen in Figure 14, which show how under these assumptions, least developed regions could increase their production compared to that under the reference 2°C scenario, while production from the most developed regions would be constrained. For both oil and gas, a low quota results in a redistribution of up to 10 per cent per annum (in the case of oil, this increase comes primarily at the expense of production from the 'very high' HDI group). Under a high quota, there are almost no immediate benefits, and a strong redistribution only occurs after 2040. In the case of oil, the limited change prior to 2040 is due to relative cost competitiveness of 'high' HDI group, which includes low-cost Middle East producers.

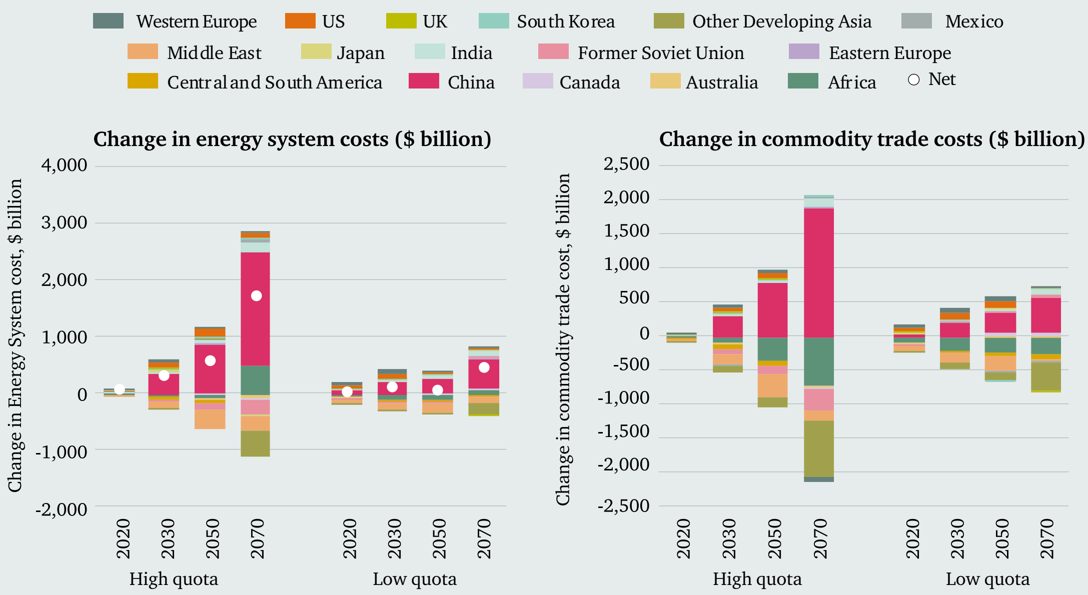
[140] McGlade and Ekins (2015), 'The geographical distribution of fossil fuels unused when limiting global warming to 2°C.'
[141] Kartha, S. (2016), *Fossil Fuel Production in a 2°C World: The Equity Implications of a Diminishing Carbon Budget*, Discussion Brief, Stockholm: Stockholm Environment Institute, https://www.sei-international.org/mediamanager/documents/Publications/Climate/SEI-DB-2016-Equity-fossil-fuel-production-rents.pdf (accessed 31 May 2018).
[142] Caney, S. (2016), *Climate Change, Equity, and Stranded Assets*, Oxfam America Research Backgrounder, Washington, DC: Oxfam America, https://www.oxfamamerica.org/static/media/files/climate_change_equity_and_stranded_assets_backgrounder.pdf (accessed 31 May 2018).

Figure 14: Oil and Gas production to 2070, by region, under an HDI-differentiated production quota

Source: UCL analysis with TIAM-UCL, 2017.
Note: Percentage change in gas production by HDI group relative to the total 2D scenario production level under a high quota (left), and low quota (middle). Total gas production in 2070 by HDI group shows the reallocation (right). The dashed line indicates NDC level relative to 2D scenario, for 'Low-medium' countries.

The wider implications of integrating equity considerations in the allocation of fossil fuel production are shown in figures 15 and 16. Figure 15 shows how the reallocation of production results in higher net system costs overall, particularly under the high redistribution, where annual systems costs increase by 2.1 per cent by 2050 and 4.4 per cent by 2070. There is, then, a clear trade-off between optimality and equity. Figure 16 shows how the increase in costs due to reallocation would negatively impact those regions without large fossil fuel resources, who may be highly import dependent; the changes in both system and commodity trade cost are borne largely by China, shown in pink. This reflects the fact that a 'development first' perspective is inherently a producer perspective; equity for net producers may not result in equity for net consumers.

Figures 15 and 16: Changes in system and commodity trade cost under a 'development first' case



Source: UCL analysis with TIAM-UCL, 2017.

While these governments might welcome the consideration of equity in policy discussions regarding future fossil fuel supply, the initial findings of 'development first' modelling suggests that the reallocation of remaining fossil fuel production does not necessarily yield economic benefit for developing countries. This is before the wider decarbonization trends addressed in this paper are considered. The reallocation of production may not yield any net benefit where the costs of production exceed the market price. This is the case for many producers in sub-Saharan Africa, for instance, where reallocation to the region would imply the development of high-cost resources.

Source: UCL and Chatham House modelling and analysis. See Annex II for full methodology.

Developing consensus among international development actors

As stated in Chapter 2, the clear signal sent by the G20 regarding the risks that climate change might present to the global financial system has been critical in furthering international cooperation around scenario analysis and carbon risk disclosure (through the TCFD). With rising levels of external debt in (often resource-driven) developing economies, the IMF is now warning about the risk of an impending debt crisis.[143] In this respect, the failure to manage carbon in developing economies may also contribute to wider fiscal stability risks. This is not just an issue for the IMF and World Bank, but also for the commercial banking sectors of many advanced economies, which have increasingly lent to higher-risk emerging economies in search of better returns, given the low interest rates elsewhere (and on the assumption that the IMF would intervene in the event of non-payment).

MDBs and major donors are well placed to raise the issue of carbon risk in fossil fuel-driven developing economies on the international agenda. Given its role in furthering international cooperation on the development of standardized carbon risk metrics and frameworks (through the TCFD), the G20 presents

[143] IMF (2018), Macroeconomic Developments and Prospects in Low-Income Developing Countries – 2018, IMF Policy Paper, May, http://www.imf.org/en/Publications/Policy-Papers/Issues/2018/03/22/pp021518macroeconomic-developments-and-prospects-in-lidcs (accessed 31 May 2018).

a leading forum in which to do this. The G20 has frequently made commitments to assist developing countries in sub-Saharan Africa and Southeast Asia, for instance, through its Energy Principles and its New Industrial Revolution action plan. Meanwhile, it pushed green finance up the international agenda when China was chair of the G20 in 2016. Raising the issue of how developing countries can manage carbon risk on the G20 agenda could help build consensus among member states, other donor countries such as Norway, and developing countries on the need to develop new approaches to managing carbon risks and transition in assistance to the developing countries with fossil fuels.

To be effective, this will require engagement with a growing range of non-traditional donors. These include emerging economy countries and their export-import banks, OPEC, Arab and Islamic development banks, new multilateral banks such as the BRICS, NDB and the AIIB, as well as philanthropic trusts. As MDBs reconsider and re-allocate development finance and assistance in line with international climate commitments, there is a risk that assistance from different actors supports conflict development models. This makes deepening cooperation with non-traditional donors – and particularly the Asian MDBs, policy banks and ECAs, which provide the vast majority of finance for coal-fired power – even more important.

Supporting the transition away from high-carbon dependencies

The rapid acceleration of climate finance is critical to the deployment of energy efficiency and the development of low-carbon energy systems, as well as the protection of critical forests and ecosystems services. The Paris Agreement set out a roadmap for richer countries to mobilize $100 billion a year in climate finance for developing countries from 2020.[144] Policy and technical advice around climate finance can help prepare the business environment and 'crowd-in' green finance and sustainable investment, as well as support the development of local SMEs. These are critical parts of the picture, but in their current form, they do not fully engage with the challenges faced by countries with existing or growing national dependence on the fossil fuel sector, or the political-economy barriers that fossil fuel development may present to NDC implementation and green growth ambitions.

The rapid acceleration of climate finance is critical to the deployment of energy efficiency and the development of low-carbon energy systems, as well as the protection of critical forests and ecosystems services.

This demands better understanding of how finance can be channelled to programmes that support the sustainable diversification of exports, a reduction in domestic dependence on imports, and the development of an autonomous monetary system and domestic financing capabilities.

Effectively addressing structural barriers to transition

Working with ministries of finance to encourage longer-term perspectives on fiscal and current account risk related to export prices, as well as valuation, pricing and taxation strategies, which take into account both global and national transitions, is one entry point for MDBs and donors. The EBRD is currently trialling this approach in two of its fossil fuel producing countries, Kazakhstan and Egypt, with the objective of building a carbon risk strategy to augment its focus on enabling countries' sustainable transition to market economies (see Annex I).

[144] UNFCCC website, Climate Finance, https://unfccc.int/topics/climate-finance/the-big-picture/climate-finance-in-the-negotiations (accessed 21 Jun. 2018).

It is far from proven that climate finance, green finance and other mechanisms will be able to offer a comparable alternative to large-scale oil and gas development, in terms of short-term investments and access to regular inflows of foreign exchange (via exports). Not only have least developed countries found it difficult to access climate finance in the past, but it does not alone provide an alternative value proposition for most producers. Renewable energy, for example, will not generate the kind of economic 'rents'[145] that countries including Nigeria, Angola, Sudan and South Sudan have grown accustomed to.

For those countries facing the challenge of reducing dependence, questions will include how to replace lost foreign exchange flows, readdress the balance of trade and develop an increasingly autonomous monetary system with an expanding tax base and growing domestic financing capacity, thereby reducing reliance on external debt. Where fossil fuel driven economies are concerned, MDBs and donors should consider whether and how climate finance, concessional finance and other investments can help create the conditions for transition; for example, how can climate finance and green growth opportunities including energy efficiency, RE and circular economy approaches be harnessed to help broaden the tax base.

MDBs can play a role in providing credit enhancements to crowd-in private finance into infrastructure that enables a low-carbon pathway in the domestic economy. Banks and other commercial investors are interested in the ways that these low-carbon investments (often too small and difficult for them to assess and evaluate individually) can be packaged to reduce their risk. Such packages could be linked to national and international decarbonization objectives, and could have the objective of 'levelling the playing field' and providing viable alternatives to fossil fuel development, where the primary intended use of fossil fuels is domestic. As stated above, country NDCs and long-term 2050 plans under the UNFCCC provide valuable guidance in this context.

Enhancing country capacity

Practically, there are several ways that MDBs and donors can better coordinate support for fossil fuel-related sectors and good governance with support for climate-smart, green growth. As stated in Chapter 1, for many donors, policy and technical advice is their sole form of support to the sector. Chapters 3 and 4 demonstrate the need and the demand for better information and capacity to manage an evolving range of carbon-related risks at country-level. This entails first allowing understanding of the economy wide implications of carbon risk to inform country assistance, and second incorporating new approaches into existing assistance programmes for both established and prospective producers.

Broadening the perception of carbon risk

For countries depending on fossil fuels exports or expecting large production expansions, assessing carbon risk means not only thinking about the carbon intensity of the fossil fuel sector (e.g. increasing its efficiency, reducing flaring) but thinking about the economy-wide impacts of upstream decisions. Oil and gas sector approaches to carbon risk tend to focus on the fossil fuel sector itself and on fossil fuel supply – for example, Tanzania's stated efforts to mitigate carbon risk focus on deployment of natural gas in place of firewood and charcoal, and converting vehicles to run on CNG.[146]

[145] Economic rents in the context of oil and gas producing countries are the money that governments receive for licensing the right to explore and produce on their territory.
[146] Tanzanian government representative at the Washington DC workshop.

This is a narrow approach compared to that taken by more established producers such as Mexico, UAE and Malaysia. For these countries, resilience means putting in place market mechanisms to avoid exposure to carbon risk and to guide the economy, such as developing shadow carbon prices within the NOC and wider economy, re-evaluating the price for vital resources in the domestic economy, including fossil fuels, water, air, and land, as well as planning for an economy-wide transition away from the sector.

Where prospective and early-stage producers are concerned, MDBs and donors can play an important role in the development of replicable analytical approaches, including scenario analysis that considers the full range of revenue and fossil fuel supply scenarios, as well as emissions and other externalities, which can, in turn, help inform resilient long-term decision-making where the role of oil and gas is concerned.

Developing the information and tools to support decision-making

There is a clear role for donors and MDBs in building the evidence base and processes required in making a decision over whether or not to proceed with exploration or the development of oil and gas discoveries, particularly where marginal, higher-cost reserves are concerned. This requires the accurate valuation of land, air quality and environmental services, as well as an assessment of the economic and societal trade-offs associated with different development pathways, particularly where decisions are based on the value of land, water and its potential alternative uses.

Support for the development of approaches such as natural capital accounting (NCA) and payments for ecosystem services tend to be situated in ministries of environment or agriculture but to take real affect they will need to be mainstreamed in central banks, treasuries, ministries of finance, energy and of national planning. Capacity-building could build on ongoing work on mapping and accounting for natural capital, including in Ethiopia, Madagascar, Uganda, Mozambique and Kenya and benefit from South–South learning.[147]

Working through these issues effectively will require listening to voices from other government entities and civil society areas of expertise. The political economy that forms around the fossil fuels sector tends to reinforce its prominence over others in national development expectations, even before production begins. There will always be other national institutions and groupings whose perspective and engagement can represent a broader set of views. Ministries or committees on national planning, agriculture, forests, fishing and national parks and tourism as well as regional and local communities all have interest in areas of the economy and industries whose prospects will be affected by the development of fossil fuel resources and associated power and industrial infrastructure.

Coordinating policy and technical assistance in country

Economic governance and fiscal reform

As chapters 3 and 4 highlight, the risk presented by the 'worst case' for fossil fuel investment and demand will play out differently between the oil and gas sectors, and from country to country. Countries could improve resilience by conducting 'carbon stress tests' around fossil fuel revenues over the next 30–50 years, including under the most disruptive climate scenarios, and considering the resilience of energy, industrial and national development plans under each of these scenarios.

[147] For instance in follow up to the 2012 Gaborone Declaration for Sustainability in Africa, which Ghana and Tanzania committed to, see Gaborone Declaration for Sustainability in Africa, 'Ecosystem Valuation and Natural Capital Accounting', http://www.gaboronedeclaration.com/nca/ (accessed 31 May 2018).

Working with ministries of finance to encourage longer-term perspectives on fiscal risks presented by uncertainty around export revenues and the time frame for diversification (including the sustainability of imports and external debt), is one entry point for MDBs and donors.

Support for carbon pricing and taxation strategies, which take into account both global and national transitions, is another. With MDBs, donors, investors and companies – including IOCs – increasingly applying a carbon price to investment assessments and screening, country governments must be better equipped to see their economies and development prospects through this lens. Development partners can help to build carbon accounting capacities within the relevant agencies such as central banks, treasuries and ministries of finance, ministries of energy, NOCs, and national planners. Effective support for green growth may also provide leverage to broaden the national tax base, given its bottom-up characteristics compared to the very narrow tax base that fossil fuel-led development tends to lock in.

There is already consensus among extractives advisers and the majority of developing countries on the importance of revenue transparency as a means of improving accountability for management of the fossil fuel sector. Where revenues are already flowing, greater accountability for how they are spent and whether these contribute effectively to economic diversification is an issue of great interest to society and particularly younger generations in fossil fuel exporting countries, and can be used to foster consultative processes.

Integrated approaches to upstream, energy and climate planning

In light of the global investment trends defined in Chapter 2 and the carbon trends outlined in Chapter 3, the development of new fossil fuel resources and related power infrastructure requires very careful risk assessment. The cost of large-scale solar continues to fall – with record low RE tariffs continuing to be set at auction in India, Mexico, UAE and other emerging markets on a regular basis. At the same time, established, low-cost producers such as Saudi Arabia are likely to drop their attachment to depletion policy based on the logic that 'production ratio is no longer such a sign of strength. Better to have money in the bank than oil in the ground.'[148] As a result, low-income fossil fuel producers are likely to face increasing pressure to offer better terms to upstream investors and to accept the conditions from importing countries wishing to offer long-term credit i.e. for future power and related industrial infrastructure.

Development advisers generally agree on the need for better coordinated and more holistic approaches to planning for energy and infrastructure (including upstream, power sector and transport sector). Those that already provide assistance to upstream fossil fuels and wider energy sector are well placed to support governments in more integrated assessments and planning capacities, which take a multi-sector approach to risk and incorporate a wider range of trade-offs, costs, externalities and options. USAID's Integrated Resource and Resilience Planning (IRRP) is one approach to strategic energy planning that has been trialled in Ghana and Tanzania, which takes into account costs, centralized and distributed energy, demand side and efficiency measures and more recently, climate change impacts.[149] DFID has also committed to a 'whole system' approach to its work on energy and climate. The aim is to begin with assessing demand for energy services by poor households and firms, and look back across the stages (and delivery modalities) of energy systems needed to deliver these e.g. distribution, transmission, and generation, and upstream decisions on extraction (see Annex I).[150]

[148] Fattouh, B. and Dale, S. (2018), *Peak Oil Demand and Long-Run Oil Prices*, Energy Insight: 25, Oxford Institute of Energy Studies, pp. 6–7, https://www.oxfordenergy.org/publications/peak-oil-demand-long-run-oil-prices/ (accessed 31 May 2018).
[149] ICF (2017), 'Integrated Resource and Resilience Planning (IRRP)', https://www.icf.com/projects/international-development/energy-efficiency-for-clean-development-program/integrated-resource-and-resilience-planning-irrp (accessed 31 May 2018).
[150] Another interesting initiative is the Energy Modelling Platform for Africa (http://www.energymodellingplatform.org/africa.html), supported by the United Nations Development Programme and UNECA amongst others – which hopes to help develop capacity on this.

Integrated planning can also raise traditional energy security questions, the response to which is likely to involve decisions in favour of greater diversification and increasing the share of RE in the energy mix. A country that relies on one gas field and one pipeline, for example, has clear energy security vulnerabilities.

The systems approaches mentioned above are relatively new, and would benefit from a stronger evidence base showing how fossil fuel development may impact on other development priorities. IRRP, for example, does not yet incorporate the costs of the externalities of energy choices including emissions, land-use change and water demand. Gas pricing, as noted above, remains an important factor where gas is expected to displace higher-carbon activities.

Box 10: Re-thinking supply and demand

Moving away from a supply-led approach and towards an 'energy services' perspective can help more accurately project demand growth. In the development of models and scenarios, there is a risk of leaving assumptions unstated, such as the level of ambition, the role of CCS or the acceleration of low-carbon technologies. There is also a risk of reinforcing mainstream narratives that suggest ever growing demand for energy, and that underestimate the contribution of efficiency, improved planning, RE and new technologies and business models. Such demand scenarios are frequently cited as justification for large-scale supply-side loans and assistance.

In this context, the importance of demand-led planning should be re-stated. There is an old discussion that 'development' looks like what happened in the global North yet energy systems in these countries developed in response to demand. An energy system shaped by a top-down perception of what development 'should' look like may result in large-scale losses. Integrating new technologies including RE and decentralized technologies in established, centralized systems is a great challenge for advanced economies. Avoiding the problems of an entrenched system demands special attention in countries with low-energy access, which plan rapid development of grid systems.

Donors can play a key role here in enhancing country capacity and improving decision-making. USAID's 'Greening the Grid toolkit', for instance, helps countries use policy, market and regulatory measures to integrate traditional and new, centralized and decentralized energy through grid-integration road maps.[151] Developing effective markets to support new, flexible business models and enable competition between product 'solutions' rather than fuel supply e.g. light, cooling or pumping is another area worth special attention, particularly in rural areas.

Planning for the fossil fuel sector along a time frame for transition

Development assistance to the upstream should ultimately help countries plan for transition. Key agencies – fossil fuel ministries, petroleum sector regulators, NOCs – are frequently represented in good governance and technical capacity dialogues, and MDB and donor experts in extractives often seconded or involved in training. These experts are of course shaped by their experience; many are veterans of the oil and gas sector. Agencies funding or leading good governance programmes, strategic and technical advisory programmes for the upstream sector could make an immediate difference by ensuring the inclusion of expertise and skills to effectively align the sector's development with NDC implementation and green growth. Much could be also be gained from peer-to-peer exchanges between established NOCs and emerging ones sharing practical lessons learnt, for example around emissions management, carbon pricing and markets, and the integration of energy efficiency measures and RE within the industry, as well as the reform of long-term commercial strategies and national mandates.

[151] USAID, (2018), Greening the Grid Toolkit, http://greeningthegrid.org/ (accessed 31 May 2018).

6. Conclusion

Global climate action is changing the growth prospects for fossil fuel producing countries. This paper considers what global climate policy and decarbonization trends mean for lower-income countries that plan to develop their oil and gas reserves to drive economic development, or are already doing so. There are clear evolving market trends and uncertainties around fossil fuels as export commodities, as well as risks that increased domestic production (and use) may present for the delivery of country green growth ambitions and NDC targets and long-term emissions reduction strategies.

Greater competition between fossil fuel producing countries for market share of fossil fuel supply to the transport and power sectors of key markets over the next two decades is inevitable. Many lower-income countries are higher cost producers and lack infrastructure and capacity, putting them at a disadvantage as late entrants to these markets in which the lowest cost producers aim to maintain or increase their market share. At the same time, those developing countries that have yet to begin fossil fuel production or develop dependencies on export revenues, or fossil fuel-fed power systems or industries are at an advantage compared with more established producers, where incumbent interests and the much higher 'social costs' of radical reform may present major barriers to transition.

> For donors and financiers, there remains some conflict between the commitment to the 'well below 2°C pathway' in terms of climate change mitigation and their development assistance to the fossil fuel sectors of developing countries.

For donors and financiers, there remains a conflict between the commitment to the 'well below 2°C pathway' in terms of climate change mitigation and development assistance to the fossil fuel sectors of developing countries. To deliver the long-term goal of the Paris Agreement in the least disruptive and least expensive way, fossil fuel use has to fall quickly – coal almost immediately, oil by 2030 and gas by around 2045. This does not mean fossil fuel supply 'quotas', but it does require a more nuanced approach to the ways in which development assistance can help identify carbon risk and the barriers to transition at the national economy level, promote economic stability and green diversification, and act as a counterbalance to the influence of political interests, which may override shared national interests in low carbon, sustainable development.

How MDBs and donors engage in this conversation needs to be considered against changing patterns in international investment. Commitment to the disclosure of climate-related financial risks (including carbon risk) and interest in green finance and sustainable investment is rapidly growing among investors, central banks and regulators. At the same time, MDBs and donors are accelerating their climate finance commitments, and moving to de-risk private sector investment in climate resilient green growth areas. Yet reforming development assistance to the fossil fuel sector has proven challenging, and where donors have taken clear policy positions, on coal for instance, other actors have quickly filled the investment gap. This highlights the need for coordination within MDBs and donor agencies, and between them.

Recommendations

New approaches to managing carbon risk

The sustainable investment needs of the global energy transition and its impacts on global financial stability are commanding increasing attention at the international level. Yet the economy-wide implications for countries that are counting on their fossil fuels for development remain poorly understood and largely unprepared for. In order to address these issues, country decision-makers should:

- **Build understanding of a country's exposure to carbon risks and its time frame for transition through the development of multi-decade scenario analyses.** These should consider the interaction between production, revenues and demand under different climate constraints. While such scenarios will always be imperfect, the process of developing them can help identify the nature of carbon linkages between the fossil fuel sector and the wider economy, including the potential range of revenues a country might expect. They can also help 'carbon stress test' plans and policies, and ensure resilience to a 'worst-case' scenario for fossil fuel investment and demand. MDBs and development agencies should work with governments to develop replicable, analytical approaches to carbon risk, and build capacity to utilize them.
- **Develop economy-wide approaches to carbon-related risks and opportunities, alongside the development of NDCs and long-term emissions reduction plans to 2050 under the United Nations Framework Convention on Climate Change (UNFCCC) process.** Countries at an earlier stage of exploration or production have the opportunity to avoid entrenching high carbon dependence through their decisions over fossil fuels development, infrastructure and energy. Where fossil fuel production is underway, the focus is likely to be on developing policies and mechanisms to mitigate carbon risk and support low-carbon transition as part of sustainable economic diversification.
- **Where capacity permits, establish a cross-government 'transition dialogue' to scope the country-specific carbon risks and opportunities that a decarbonizing world presents.** This could focus on economy-wide implications, from the energy and industrial pathways that fossil fuel development might lock-in to fiscal stability implications (including the sustainability of debt) and impacts on the wider investment environment for climate finance and for the country's broader economy. This should be championed at cabinet level, and bring together stakeholders from government institutions related to finance, national planning, energy and power, environment and climate, and oil and gas, among others. Such discussions could also foster consultative processes that proactively manage societal expectations.

Building country-level capacities and institutions for transition

Countries and their advisers should review traditional 'good governance' recommendations relating to fiscal governance, upstream oil and gas, and energy and industrial planning with carbon risks in mind. Developing effective responses will require interventions and capacity-building in those institutions that play a leading role in these areas of policy, which should:

- **Develop 'carbon risk competencies' in key areas of economic governance.** Central banks, ministries of finance and those managing SWFs should begin to develop 'carbon stress-tests' in key areas of fiscal governance by:
    - Assessing the implications of carbon linkages on domestic (and global) fiscal stability, including budgetary dependence on fossil fuel revenues. The current account impacts of growing local fossil fuel consumption (including rising import dependence, often including on fossil fuel products) and linked infrastructure investments, and risks from borrowing against future fossil fuel production should be considered in light of the full potential range of fossil fuel revenue outcomes (and therefore foreign exchange earnings or needs) and time frames for production (and thus diversification) under different climate scenarios, including the 'worst-case' scenario for fossil fuel demand.
    - Reviewing revenue management frameworks in light of carbon risks and low-carbon opportunities, including regulations and mechanisms that allocate revenues to the national budget, stabilization and SWFs. The processes that distribute revenues through the national budget warrant special attention. Key considerations include how best to distribute revenues between short-term needs, the build out of physical and social infrastructure and long-term wealth creation, and how revenues might be used to drive clean energy and green growth and finance NDC implementation (where they are likely to arrive in time for this). The development of carbon pricing capacities can also support broader fiscal reforms.
    - Investing SWFs in a way that avoids 'double' exposure to high-carbon international assets and helps hedge the overall national balance sheet from shocks. Emerging and early stage producers should consider following the lead of the world's largest SWFs and pension funds, and develop 'best in class' investment strategies that take advantage of the opportunities presented by lower-carbon portfolios, and reduce exposure to carbon through international investments by diversifying away from or divesting fossil fuel and other high-carbon assets. Clearer guidance from established SWFs and pension funds on how they are assessing risk could help support this.
- **Design energy and industrial policy for transition.** Well-designed policies can help support the delivery of access to energy and industrialization goals, while incentivizing energy transition and green growth. Getting policy, regulation and pricing right is crucial to a country's attractiveness for climate finance and technology transfer, and will be aided by:
    - Taking an integrated, whole-system approach to energy planning. This should factor in investment needs, energy security considerations (supply disruption, rising import dependency), demand-side management options (energy efficiency, 'smart' systems), and the cost of externalities (e.g. carbon emissions, poor air quality, water stress) over time. Such tools can support policymakers in identifying the 'lowest-cost' means of delivering national sustainable access to energy and industrialization goals, and the ideal balance between on- and off-grid power supplies. These approaches must be dynamic, and able to respond to new prices and inputs.

- Using energy policy levers to incentivize efficiency and RE integration. Policymakers could begin by examining the policy and practical (finance, technology, pricing) requirements for the most sustainable infrastructure, which will facilitate the scale-up of RE over time. Developing and empowering proficient, independent regulators with a long-term mandate and the authority to ensure value for money for the government and quality of energy services for the consumer is key to getting the incentives right for the required public and private investment over time.

- Seizing the opportunities presented by urbanization and industrialization trends to help 'shape' future energy demand, through smart urban planning and the procurement of the most efficient, low-carbon designs and materials. MDBs and donors should consider how concessional finance might be used to incentivize infrastructure with the potential to be zero-carbon, and explore ways of facilitating South–South learning around the procurement, financing and delivery of urban and industrial energy systems and related infrastructure. Such an emphasis can also help shift the focus of energy discussion in fossil fuel producing countries from a supply-led approach to a demand-side, energy services perspective.

- **Prepare the fossil fuel sector for transition.** Where fossil fuel development proceeds, or is already in place, the institutions that manage and operate upstream – including ministries of energy, ministries of power, upstream regulators and state-owned extractives companies e.g. NOCs – can all develop in ways that either help or hinder carbon risk management and energy transition. To help prepare these institutions, governments could work, potentially with assistance from development partners, to:

  - Carefully consider the establishment and appropriate mandate of an NOC, given the likely time frame for transition. The distribution of risk between the state and private sector should minimize risk to public finance. Evolution of the NOC as a 'manager of carbon' may be appropriate for some, including sharing lessons learned about carbon markets (see below). Where there are ambitions to transition from an NOC to an NEC (national energy company), this should be underpinned by an open and practical conversation about the most appropriate institutions and processes to promote the integration and scale-up of RE and other clean technologies.

  - Build capacity within the ministry, regulator and/or NOC to play a role in emissions and carbon management. Energy efficiency and emissions capacities should include the procurement and utilization of RE and efficiency technologies to help reduce sector emissions, and the monitoring and mitigation of methane leakage across the supply chain. Carbon management capacities should include the application of shadow carbon pricing to upstream and power sector decision-making, where fuel supply is to be allocated to domestic energy systems. This necessitates effective coordination with power sector stakeholders and national planners, among others.

  - Share experiences and accelerate learning through the establishment of peer-to-peer learning networks. There is clear demand for peer-to-peer learning between emerging and early-stage producers and more established NOCs, petroleum sector regulators and ministries on technical issues, and on the reform of long-term business strategies and national mandates, in line with the risks and opportunities that the global energy transition presents. MDBs, donors and NGOs have an important role to play in facilitating such discussions.

Aligning development assistance with climate and country needs

Developing-country governments anticipate support for climate mitigation and adaptation. Those with fossil fuels will face unique challenges and opportunities as global energy systems are decarbonized. Without greater policy coherence within and between the providers of development assistance, the cost of transition will only grow, as dual, conflicting pathways are funded. There is urgent need for better alignment in three broad areas. To achieve this governments should:

- **Align development assistance to upstream oil and gas and linked energy and industrial infrastructure country NDCs and long-term emissions reduction plans to 2050.** Where fossil fuel development is under consideration, MDBs and donors should support country studies to explore whether this is compatible with NDC commitments and 2050 plans, allowing scope for rising climate ambition. Where development assistance to fossil fuels is made on the basis of its contribution to NDC targets – for example gas-to-power in order to displace coal- and diesel-generation or LPG to substitute biomass in cooking – development partners must be prepared to support the wider investment and capacity to effectively deliver this outcome. Where fossil fuel development conflicts with a country's NDC and wider green growth objectives, development assistance for alternative energy systems and economic activities should be coordinated.
- **Develop clear and consistent policy positions on the re-alignment of development assistance in support of the Paris Agreement, alongside private sector partners.** Policy should address the conditions for support to upstream fossil fuels and linked downstream energy and industrial activities under a 2°C scenario, as well as common approaches to the use of carbon pricing. MDBs can provide credit enhancements and package bankable projects to crowd-in private finance into infrastructure that enables a low-carbon, climate resilient pathway. At the national level, donor countries should ensure that the activities of other forms of public finance, including non-ODA policy banks and ECAs, do not conflict with their development agency objectives.
- **Enhance policy coherence at the international level.** There is a risk that assistance from different actors will support conflicting development models, further damaging prospects for sustainable growth. This makes deepening cooperation with non-traditional donors – and particularly the Asian MDBs, policy banks and ECAs, which provide the vast majority of finance for high-carbon sectors – even more important. Given its role in furthering international cooperation on climate-related financial risk and green finance, the G20 could support dialogue between G20 members (and other key donors such as Norway), participating MDBs and international organizations, and non-participating developing countries, with the objective of coordinating development assistance around these issues. This could also help provide a framework for North–South and South–South lessons-sharing and capacity-building.

Acronyms and Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
ANRC	African Natural Resources Center
BAU	business as usual
BECCS	bioenergy with CCS
BRICS	Brazil, Russia, India, China and South Africa
BRICS NDB	BRICS New Development Bank
CCS	carbon capture storage
CIFs	climate investment funds
CNG	compressed natural gas
DAC	Development Assistance Committee
DFI	development finance institution
DFID	UK's Department for International Development
EBRD	European Bank for Reconstruction and Development
FDI	foreign direct investment
FSB	G20 Financial Stability Board
GDP	gross domestic product
GHGs	greenhouse gases
GOR	gas-to-oil ratio
HDI	UNDP Human Development Index
IDA	International Development Association
IEA	International Energy Agency
IFC	International Finance Corporation
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IOC	international oil company
IRRP	USAID's Integrated Resource and Resilience Planning
LNG	liquefied natural gas
LPG	liquid petroleum gas
MDB	multilateral development bank
MDTF	multi-donor trust fund
NDC	Nationally Determined Contribution
NET	negative emissions technology
NFO	Netherlands Development Finance Company
NGO	non-governmental organization
NOC	national oil company
Norad	Norwegian Agency for Development Cooperation
ODA	overseas development aid
OECD	Organisation for Economic Co-operation and Development
OfD	Norad Oil for Development
OPEC	Organization of the Petroleum Exporting Countries
PPP	public–private partnership
PSC	production sharing contract
RE	renewable energy
REDD+	UN Programme on Reducing Emissions from Deforestation and Forest Degradation
SDGs	Sustainable Development Goals
SOE	state-owned enterprise
TCFD	Task Force on Climate-Related Financial Disclosures
UCL	University College London
UKEF	UK Export Finance
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNEP	UN Environment Programme
UNEP FI	UN Environment Programme Finance Initiative
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

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Glossary

Development actor, institutions and mechanisms

Development assistance, development finance, bilateral donors/donor countries, non-traditional donors, development agencies, export credit agencies (ECAs), multilateral development banks (MDBs) – see Box 2 for full definitions of each.

Fossil fuels, energy and infrastructure

Fossil fuels – All hydrocarbon fuels including oil, gas, coal and their derivatives

'High-carbon' fuels – Fuels that entail a high-carbon cost, mainly hydrocarbon fuels, including unsustainably produced and burned wood and charcoal.

Upstream (fossil fuel sector) – The exploration and production activities for oil, natural gas and coal including infrastructure e.g. drilling rigs, LNG terminals and pipelines to LNG terminals for export.

Midstream (fossil fuel sector) – Pipelines and other forms of transportation from production sites to refineries, power plants and natural gas processing plants.

Downstream (fossil fuel sector) – Natural gas processing, oil refining, and the marketing and delivery of refined products. This is different to 'linked industries' (see below).

Fossil fuel sector – All industries throughout the value chain, from the upstream to the downstream, as defined above, that are concerned with the direct production and marketing of fossil fuels.

Fossil fuel-linked industries – This includes thermal power generation, which relies on inputs of gas, coal or oil, and energy-intensive industries including steel and aluminium, petrochemicals, fertilizers and cement. It is worth noting the distinction between fuel used as an energy source and fuel used as a direct input – as with coking coal in steel production and oil and gas in the petrochemicals and fertilizers production. In this paper both types of input are considered as a 'linkage'.

Energy sector – This refers chiefly to the industries and government agencies, which manage and deliver domestic energy needs in terms of electricity, transport and fuel and increasingly deal with energy services such as heating, lighting and cooking. Others may also use the energy sector to encompass the hydrocarbons sector.

Infrastructure – Built infrastructure in the upstream, energy and industrial sectors. See Chapter 3 for the scope of infrastructure considered by this paper.

High-carbon, low-carbon and transition

Decarbonization – The shift away from man-made systems that release carbon dioxide into the atmosphere, and towards a zero-carbon system. This can be through both ceasing emitting practices and by capturing CO_2 via forest 'sinks' and NETs.

Low-carbon development – This is synonymous with low-emission development and low-carbon growth, and entails raising standards of living and eradicating poverty in ways that entail minimal output of carbon dioxide emissions. This can be understood as a subset of 'green growth' (see below).

Low-carbon transition – This is the process that countries with existing high-carbon industries and infrastructures undertake in order to reduce emissions intensity and continue development along a lower-carbon pathway. This could include retrofitting existing energy and energy-using infrastructure, and introducing economic mechanisms to put a price on emissions.[152]

Carbon transition risks – In the context of this paper, these are factors that are likely to make low-carbon transition more expensive. The particular physical infrastructure, fiscal structure and political economy characteristics that fossil fuel-led growth encourages can undermine a country's capacity to diversify the economy and may present particular obstacles to low-carbon growth, e.g. high-carbon power and energy using infrastructure, large carbon-intensive industries, fuel subsidies, low levels of private sector competition and vested interests in the status quo.[153] Countries that have grown their economy around fossil fuels exports are likely to face increased transition risk.

Carbon risks – This term is often used in an investment context to refer to investor exposure to businesses or assets that may lose value in future due to decarbonization trends – particularly the transition of energy systems away from the use of fossil fuels. In this paper, the concept is broadened to refer to the economic risks that global decarbonization poses to countries either already dependent or considering increasing the export of high-carbon fuels and their use domestically.[154] In this paper this term is treated differently to 'transition risk', although it is acknowledged that the two are used interchangeably in much of the commercial and institutional investment literature on the matter.

Low-carbon opportunities – These are opportunities that countries and businesses have to access cleaner forms of energy and more energy and resource-efficient industrial technologies, built infrastructure, and urban and architectural design. It also includes access to finance, including 'green' investment opportunities and 'climate finance' provided chiefly by MDBs and donor countries.

Diversification and sustainability

Economic diversification – This is the process of broadening the number of economic sectors that contribute to a country's income and growth. As a strategy, it is mainly used when one sector (e.g. oil and gas or mining) effectively supports the rest of the economy, potentially leaving the country vulnerable to fluctuating export prices and failing to create broad-based employment. The traditional model of diversification in oil and gas-dependent developing countries has been the development of industry (e.g. petrochemicals, fertilizers, steel and cement) around the 'leading sector', often using cheap fuel inputs in industry and thermal power generation. This paper distinguishes between this 'depletion-based diversification', which is unsustainable, and 'sustainable diversification'.

Sustainable diversification – This enables and promotes broad-based economic growth in ways that are not dependent on the fossil fuel sector and that can sustain themselves when fossil fuel sector revenues decline. In a country that is already highly dependent on fossil fuels, this term would also entail the shift away from a 'rent-based' economy towards stimulating greater 'productivity'. It is also significant for countries developing their fossil fuels sector in terms of how they incentivize growth of other sectors.

[152] Bailey, R. and Preston, F. (2014), *Stuck in Transition: Managing the Political Economy of Low-carbon Development*, Briefing, London: Royal Insitute of International Affairs, https://www.chathamhouse.org/publications/papers/view/197606 (accessed 30 May 2018).
[153] Friedrichs, J. and Inderwildi, O. R. (2013), 'The Carbon Curse: Are Fuel Rich Countries Doomed to High CO_2 Intensities?', *Energy Policy,* Volume 62, November 2013, Pages 1356–1365, https://doi.org/10.1016/j.enpol.2013.07.076 (accessed 30 May 2018).
[154] Lahn, G., and S. Bradley (2016). 'Left Stranded? Extractives-led Growth in a Carbon-constrained World'. EER Research Paper. London: Chatham House.

Green Growth – There is no universally agreed formula for green growth. This report uses the concept of low-carbon green growth as set out by the Global Green Growth Institute: 'fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. It focuses on the synergies and trade-offs between the environmental and economic pillars of sustainable development.' Crucially, it 'discards the traditional convention of "grow first, clean up later"'.[155]

Unburnable reserves and stranded assets

Unburnable carbon – These are fossil fuel resources that cannot be burned within a 2°C carbon budget. The exact level of unburnable carbon will depend upon the chosen 2°C pathway. This does not mean political or legal restrictions on developing fossil fuels; it is more likely to mean that fossil fuels lose their value on the global market, due to changes in demand and technology, so the reserves are no longer commercially viable and do not attract the necessary investment to enable production. This is different to the concept of 'stranded assets'.

Stranded assets – In the context of decarbonization, this refers to those physical assets that have received investment, and which lose their commercial value as other technologies displace demand for the product. Carbon Tracker defines them as 'fossil fuel supply and generation resources which, at some time prior to the end of their economic life (as assumed at the investment decision point), are no longer able to earn an economic return (i.e. meet the company's internal rate of return), as a result of changes associated with the transition to a low-carbon economy.'

[155] ADB and Asian Development Bank Institute (2013), *Low-Carbon Green Growth in Asia: Policies and Practices*, Tokyo: Asian Development Bank Institute, pp. 1–2, https://www.adb.org/sites/default/files/publication/31225/20130628book-low-carbongreen-growthasia.pdf (accessed 31 May 2018).

Annex I: MDB and Donor Case Studies

The World Bank Group's support to energy, extractives and climate change[156]

The World Bank Group (WBG) has 189-member countries and is composed of five institutions including: the International Bank of Reconstruction and Development (IBRD), the International Development Association (IDA), the International Finance Corporation (IFC) and the Multilateral Investment Guarantee Agency (MIGA).

The World Bank Group recognizes that its twin goals of ending extreme poverty and boosting shared prosperity cannot be achieved 'without tackling climate change'. In 2017 alone, the WBG provided $12.8 billion in financing to over 200 climate-related projects. It has indicated that it will increase climate financing to 28 per cent of its portfolio – or around $29 billion per year by 2020. It has set out five priorities for this finance commitment:

- Integrating climate change into development priorities;
- Accelerating the energy transition;
- Facilitating expansion of sustainable infrastructure;
- Boosting the climate resilience of communities and ecosystems; and,
- Unlocking private finance for greater benefits.

Beyond being the largest multilateral financier of climate action in the world, the WBG also hosts the Climate Investment Funds, which have provided cutting edge climate expertise and financial support to developing countries for the past 10 years. This includes the Clean Technology Fund, which has been a key driver of frontier technologies, including Concentrated Solar Power. The World Bank was a first mover on supporting the establishment of global carbon markets. It created the first ever carbon fund and today is trustee of 15 carbon initiatives. These funds have supported more than 145 active projects in 75 countries and since 2000, these initiatives have reduced the equivalent of 187 million tons of carbon dioxide emissions. The WBG is also a leading global advocate for carbon pricing, leading and hosting the Carbon Pricing Leadership Coalition, which continues to mobilize political and business leadership for carbon pricing. The WBG is among the world's leaders and largest issuers of green bonds, raising over $16 billion in over 200 green bonds since 2008 for climate and environment-related investments.

Recognizing the importance of the extractives sector to many resource-rich developing country economies, the WBG provides extractives-related development assistance that focuses on effective governance, transparency, and financial, social and environmental sustainability. Cumulative investment over the past decade has been about $3.3 billion. The WBG believes that if managed

[156] Based on World Bank (2016), *The World Bank Group in Extractive Industries – Annual Overview 2016*, http://www.ifc.org/wps/wcm/connect/9703eec3-927a-49b6-ba33-9d8f4fd2ac63/WBG-in-Extractive-Industries-2016-Annual-Review.pdf?MOD=AJPERES (accessed 31 May 2018); World Bank (2017), 'Climate Change Overview', http://www.worldbank.org/en/topic/climatechange/overview#1 (accessed 31 May 2018); IFC (2017), 'Oil, Gas and Mining Overview', http://www.ifc.org/wps/wcm/connect/Industry_Ext_Content/ifc_external_corporate_site/OGM+Home (accessed 4 Jan. 2018); World Bank (2017), 'Climate Finance', http://www.worldbank.org/en/topic/climatefinance (accessed 31 May 2018).

effectively, the sector can help provide jobs, shared infrastructure, government revenues, and benefits for local economies. The IFC states that its goal in oil, gas and mining is to 'help developing countries realize these benefits, while helping promote sustainable energy sources'.

In line with the WBG's commitments to the Paris Agreement and to help countries accelerate the transition to sustainable energy, policy is moving away from support for high emissions sectors. As outlined in its 2013 Energy Sector Directions Paper, the WBG can only provide financial support for greenfield coal power generation projects in 'rare circumstances', such as to meet basic energy requirements in countries with no feasible alternatives to coal. The WBG has not financed a new coal-fired energy project since 2010.

In 2017, the WBG announced that it would no longer invest in new upstream oil and gas after 2019 'unless under exceptional circumstances' – where there is 'clear benefit to energy access, and this is consistent with countries' NDC commitments'. This decision does not affect finance to natural gas investments for transport, distribution and power generation.

As of 2017, the WBG began to design and apply shadow carbon pricing to its economic analysis of projects in high-emitting sectors with the intention of mainstreaming this practice.

The African Development Bank: Towards mainstreaming climate policy[157]

Aligning climate, extractives and good governance goals is a priority for the AfDB given that 51 of its 54 member countries are exploring for or producing petroleum and all will be deeply affected by climate change. The AfDB projects that the region's total extractive-based annual government revenue will reach $30 billion over the next 20 years. In spite of the economic potential, the AfDB recognizes the history of regulatory and governance weaknesses, environmental and human rights impacts, and poor redistribution of resource wealth to citizens. Meanwhile, adapting to climate change over this period is expected to cost the continent around $7–$15 billion per year by 2020, increasing to $35 billion annually by the 2040s, and up to $200 billion annually by the 2070s in a world in which temperatures rise by 4°C above pre-industrial levels.

The AfDB's Ten-Year strategy (TYS) 2013–2022 is thus strongly invested in two concepts:

- Inclusive growth – Broadening prosperity across age, gender and geography, with deep reductions in poverty and increasing economic opportunity.
- Green growth – Transitioning the continent to growth that will protect livelihoods, improve water, energy and food security, promote the sustainable use of natural resources, build resilience to climate shocks, and spur innovation and economic development. This includes 'green industrialization'.

Alongside the TYS is the AfDB's Second Climate Change Action Plan (2016–2020). The AfDB is committed to devoting 40 per cent of its total financing – $5 billion a year – by 2020 to climate-related projects and plans to achieve parity in financing mitigation and adaptation projects.

[157] Based on Mwebaza, R. (2017), AfDB presentation, Ghana; AfDB (2017), *Africa Thriving and Resilient: The Bank Group's Second Climate Change Action Plan (2016–2020)*, https://www.afdb.org/en/documents/document/africa-thriving-and-resilient-the-bank-groups-second-climate-change-action-plan-2016-2020-revised-version-98936/ (accessed 31 May 2018); AfDB (2016), 'Annual Green Bonds Newsletter', Issue 3, October 2016, https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Green_Bonds_Newsletter_-_Issue_N_3_-_October_2016.pdf (accessed 31 May 2018); AfDB (2018), 'African Natural Resources Center', https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/african-natural-resources-center/ (accessed 31 May 2018).

In 2013, the AfDB created the African Natural Resources Center (ANRC) to assist its regional member countries in maximizing development outcomes derived from natural resources. This includes advice to countries and multilateral corporations on 'integrated natural resource development' plans, which adopt a long-term perspective that promotes green and blue (referring to sustainable use of ocean resources) economic principles, including initiatives to combat desertification, deforestation and degradation.

In order to mainstream climate change and green growth through its operations, the AfDB has developed several tools to inform its decision-making through the project cycle. These include a Climate Safeguards System, a Greenhouse Gas Accounting Tool and the Additionality and Development Outcomes Assessment (ADOA) among other project appraisal tools. This is driven by the idea that Africa cannot afford to 'grow today and clean up tomorrow'.

The AfDB expects to increase assistance on implementation of NDCs, some of which are hydrocarbon sector specific. Inadequate donor financing remains a major obstacle so the AfDB is focusing on access to alternative funding through bond issuance (particularly green bonds), multilateral climate funds, and private finance through public–private partnerships (PPPs).

The European Bank for Reconstruction and Development (EBRD) is supporting the 'greening' of transition economies[158]

EBRD's overall mission is to 'promote transition to open, market-based economies' in the 39 countries in which they operate – from Central and Eastern Europe, to Central Asia and the southern and eastern Mediterranean to North Africa. The EBRD works towards this goal through financial investment projects that help promote the environment for business.

Between 2006 and 2013, EBRD invested a total of €11.12 billion across 155 energy and power sector projects. Analysis of EBRD's accounts suggests that in 2006–13, support to hydrocarbons-related projects equalled around €2.5 billion. A shift towards sustainable energy has been taking place. The EBRD's revised Energy Sector Strategy for 2014–18, identifies energy efficiency as the first response to global energy security. The strategy also reinforces the Bank's growing support for renewable energy – highlighting the organization as 'an enabler' of renewables and ensuring that EBRD does not finance coal-fired generation, 'except in rare and exceptional circumstances where there are no feasible alternative energy sources'. In 2015, the EBRD also launched the Green Economy Transition (GET) approach. The approach aims to put investments that bring environmental benefits to the centre of their investment strategy, seeking to increase the volume of green financing (beginning with renewable energy and energy efficiency) from an average of 24 per cent of EBRD annual business investment in the 10 years up to 2016 to 40 per cent by 2020.

A number of the EBRD's countries of operation are producing or planning to produce more fossil fuels (including Russia, Kazakhstan, Egypt, Mongolia, Lebanon), and EBRD's most recent strategy document recognizes that fossil fuel rich countries face great uncertainties – in terms of timing, policy choices and carbon prices. Technical cooperation and support activities amount to less than 2 per cent of EBRD's assistance to the extractives resources and energy sectors, but increasingly EBRD is questioning what climate constraints mean for future growth pathways and economic stability –

[158] Based on: EBRD (2017), 'Power and Energy data', http://www.ebrd.com/cs/Satellite?c=Content&cid=1395238328614&pagename=EBRD%2FContent%2FContentLayout (accessed 31 May 2018); EBRD presentation delivered as part of the Chatham House workshop, 'Climate risks and opportunities for low-income fossil fuel producers', 6 September 2017; EBRD (2013), 'Energy Sector Strategy', http://www.ebrd.com/downloads/policies/sector/energy-sector-strategy.pdf (accessed 31 May 2018); EBRD (2013), 'Mining Operations Policy', http://www.ebrd.com/downloads/policies/sector/mining-operations-policy.pdf (accessed 31 May 2018).

particularly where fiscal policy and fossil fuel subsidies are concerned – and is now engaged in efforts to tailor policy recommendations to enhance country understanding of the channels through which climate risks and impacts may occur. One pilot initiative works with ministries of finance in two hydrocarbons exporting countries to assess how carbon risk could affect their economies over the next two decades and what measures they might put in place to build greater resilience.

The UK Department for International Development's (DFID) strategy[159]

DFID's 2017 Economic Development Strategy places economic growth, productive jobs and investment at the heart of its efforts to eradicate extreme poverty, deliver SDGs and end reliance on aid. It recognizes that extractive resources play a role in shaping a country's development path, and outlines DFID's commitment towards a low-carbon transition, including by supporting partner countries to manage their extractive resources.

DFID's extractives portfolio includes policy and regional programming that supports initiatives such as the Extractive Industries Transparency Initiative (EITI) and Skills for Oil and Gas Africa (SOGA), as well as country-level programs that provide technical assistance and capacity-building for government, civil society and the private sector. Priority areas include curbing illicit and illegal financial flows linked to the extractives sector, maximizing job creation in and around the sector, and leveraging data and technology to increase accountability in the sector. It only works directly with countries on sector development issues when invited to do so.

DFID's climate portfolio supports countries in their transition to a climate-smart future; assistance ranges from strengthening partner governments' capability to deliver on their NDC commitments, to making environment and climate-related considerations more central to development capital, and working with multilateral institutions to scale up climate finance by 2020. The need for strong action on climate change in order to ensure long-term economic and societal resilience is also stressed; particularly in light of both the rising cost of natural disasters and the rapidly declining cost of low-carbon and clean technologies.

DFID is increasingly taking a whole system approach to its work on energy and climate. It begins with assessing the demand for energy services by poor households and firms, and looks back across the stages (and delivery modalities) of energy systems needed to deliver these e.g. distribution, transmission, and generation, right back to decisions on extraction. A major focus of this approach is to strengthen alignment with other parts of the UK government (such as the Department for Business, Energy and Industry (BEIS) and the Foreign and Commonwealth Office (FCO) and ensure the UK is speaking with one voice in relation to developing countries and partners.

[159] Based on DFID (2017), *Economic Development Strategy: prosperity, poverty and meeting global challenges*, London: Department for International Development, https://www.gov.uk/government/publications/dfids-economic-development-strategy-2017 (accessed 31 May 2018); DFID's Priorities in the Energy Sector: A Policy Framework Revised Draft, 2 September 2015 (unpublished) and; DFID (2015), *Sustainable infrastructure for shared prosperity and poverty reduction: A policy framework*, January 2015, London: Department for International Development, https://www.gov.uk/government/publications/sustainable-infrastructure-for-shared-prosperity-and-poverty-reduction (accessed 31 May 2018).

Norway's development strategy[160]

Given its own successful oil industry, which is seen as a model for 'avoiding the resource curse' around the world, Norway offers technical assistance to other countries developing their petroleum. The 'Oil for Development' (OfD) programme comes under the Norwegian Agency for Development Cooperation (Norad), which sits within the Department for Economic Development, Gender and Governance and is jointly governed by five ministries including the Ministry of Petroleum and Energy, and the Ministry of Climate and Environment.[161]

OfD's role is to offer 'assistance to developing countries in their effort to manage petroleum resources in a sustainable manner'. Its primary objective is poverty reduction and it works to support this by assisting in the responsible management of petroleum resources in those countries that formally request its support. Its main functions are technical: assisting countries with the political and legal framework for the sector, building the competence of relevant authorities governing the sector, and working with civil society so that they can hold those authorities to account. To date, it has worked in about 35 countries, and currently works in 14, including some newer hydrocarbons producers.[162]

Climate change and the environment is one of the eight thematic focus areas for Norad, which states that climate change and the environment are 'the main focus for Norwegian Development Policy' and cross cutting concerns for all Norwegian development programs, including OfD. As early as 2008, Norwegian embassy reports on 'greening Norwegian development assistance' in key countries, such as Mozambique and Angola, were highlighting 'green' linkages to OfD's work, although the scope for these recommendations was typically limited to the 'greening' of oil and gas sector activity, as opposed to wider market and sustainable development risks.

More recently, in its 2014 annual report, OfD cites 'issues related to climate change' under the environment as part of its holistic approach to petroleum management. In 2016, to strengthen the environmental aspects of the programme OfD entered into a strategic partnership with the UN Environment Programme (UNEP). Meanwhile it is scaling up support for renewables and clean technologies through its Clean Energy Initiative. Norad strategy addresses climate change systematically and in various ways, conveying Norwegian experience on:

- Information about emissions from the petroleum sector, as well as legal and financial tools to reduce emissions;
- Regulations on gas flaring, which was prohibited in Norway in the 1970s;
- Application of a carbon tax, which was implemented in Norway in 1991; and
- Assistance in mapping, measuring and reporting of climate gas emissions from the petroleum sector, including as part of the NDCs under the Paris Agreement.

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[160] Based on Norad (2017), 'Oil for Development Programme', https://www.norad.no/en/front/thematic-areas/oil-for-development/oil-for-development-programme/ (accessed 31 May 2018); Norwegian Ministry of Foreign Affairs (2009), *Climate, conflict and capital: Norwegian development policy adapting to change*, Norwegian Government White Paper, Report No. 13 (2008–2009), https://www.regjeringen.no/contentassets/74c115f115304813805fa58d96e3c859/en-gb/pdfs/stm200820090013000en_pdfs.pdf (accessed 20 Feb. 2018); Norad (2015), 'Climate Proofing Tool', https://www.norad.no/en/front/thematic-areas/climate-change-and-environment/climate-proofing/ (accessed 31 May 2018); Norad (2007) 'Clean Energy for Development Initiative', https://www.norad.no/en/front/thematic-areas/energy/clean-energy/clean-energy-for-development-initiative/; Norad (2009), *Initiative for Clean Energy in Development Cooperation ('Clean Energy Programme'):* Action Plan *2009–2012,* https://www.norad.no/globalassets/import-2162015-80434-am/www.norad.no-ny/filarkiv/clean-energy-programme--action-plan-2009-2012.pdf (accessed 20 Jan. 2018); Norad (2017), *Clean Energy Initiative: Results Report 2007–2015*, https://www.norad.no/globalassets/publikasjoner/publikasjoner-2017/the-clean-energy-initiative-results-report-20072015.pdf (accessed 31 May 2018).

[161] The other ministries on OfD's steering committee are the Ministry of Foreign Affairs, the Ministry of Finance, and the Ministry of Transport and Communications, plus the Ministry of Labour Social Affairs participating as an observer in meetings. OfD also coordinates activities with the Office of the Auditor General of Norway.

[162] Countries of operations include Cuba, Ghana, Kenya, Mozambique, Myanmar, Tanzania and Uganda, and it is evaluating requests from Somalia and Colombia.

This policy framework strongly supports countries making their own choices and policies for promoting economic growth, but also aims to 'encourage countries to draw up forward-looking development strategies that are robust to climate change'. The government white paper underpinning this policy states that 'Africa now has the opportunity to choose a planned, sustainable, robust low-carbon path of development' and promotes renewable energy through its contribution to the Global Energy Efficiency and Renewable Energy Fund while Norad has a section devoted to renewable energy.

Moreover, Norway pursues a strong leadership role in the climate change mitigation agenda internationally, and implements a carbon tax regime domestically. Its sovereign pensions fund has divested from coal internationally on the grounds of both climate and financial risk.

Annex II: Methodology for the Global Scenarios

To explore the uncertainties and equity issues associated with fossil fuel production and use under different climate targets, the modelling in this paper used the TIMES Integrated Assessment Model at University College London (TIAM-UCL).[163] This model represents the global energy system, capturing primary energy sources (oil, gas, coal, nuclear, biomass, and renewables) from resource production through to their conversion (electricity production), their transport and distribution, and their eventual use to meet energy demands across a range of economic sectors.

The model has a 16 region representation, allowing for more detailed characterization of regional energy sectors, and the trade flows between regions. Upstream sectors within regions that contain members of OPEC are modelled separately, for both OPEC and non-OPEC groups of countries. Regional coal, oil and gas prices are generated within the model. These incorporate the marginal cost of production, scarcity rents, rents arising from other imposed constraints, and transportation costs.

A key strength of TIAM-UCL is the characterization of the regional fossil resource base.[164] For oil reserves and resources, these are categorized into current conventional proved and probable (2P) reserves in fields that are in production or are scheduled to be developed, reserve growth, undiscovered oil, Arctic oil, light tight oil, natural gas liquids, natural bitumen, extra-heavy oil, and kerogen oil. The latter three of these are all unconventional oil categories. For gas, these resources are categorized into current conventional 2P reserves that are in fields in production or are scheduled to be developed, reserve growth, undiscovered gas, Arctic gas, associated gas, tight gas, coal-bed methane, and shale gas. For oil and gas, individual supply cost curves for each of the categories are estimated for each region.

In the model, future demands for energy services (mobility, lighting, industrial heat etc.) drive the evolution of the system so that, an energy system in 2050 meets the energy services required, which have increased through the growth in population and the global economy. Decisions around what energy sector investments to make across regions are determined on the basis of the most cost-effective investments, taking into account the existing system in 2015, energy resource potential, technology availability, and crucially policy constraints such as emissions reduction targets. The model time horizon runs to 2100, as this is the timescale often used for climate stabilization. A climate module is also integrated into the model framework, allowing for a simple representation of the climate system. It ensures that any future energy system is consistent with a given temperature objective, such as limiting warming to 2°C by 2100.

[163] Further information on TIAM-UCL can be found on the ADVANCE project website at http://themasites.pbl.nl/models/advance/index.php/Model_Documentation_-_TIAM-UCL (accessed 31 May 2018).
[164] McGlade, C. and Ekins, P. (2015), 'The geographical distribution of fossil fuels unused when limiting global warming to 2°C', *Nature,* 517, pp. 187–190, (accessed 31 May 2018); McGlade, C. and Ekins, P. (2014), 'Un-burnable oil: An examination of oil resource utilisation in a decarbonised energy system', *Energy Policy,* 64, pp. 102–112, (accessed 31 May 2018); McGlade, C., Bradshaw, M., Anandarajah, G., Watson, J. and Ekins, P. (2014), '*A Bridge to a Low-Carbon Future? Modelling the Long-Term Global Potential of Natural Gas*, Research Report, London: UKERC, (accessed 31 May 2018); Bauer, N., McGlade, C., Hilaire, J., and Ekins, P. (2018), 'Divestment prevails over the green paradox when anticipating strong future climate policies', *Nature Climate Change*, 8, pp. 130–134 (accessed 31 May 2018); Pye, S., McGlade, C., Bataille, C., Anandarajah, G., Denis-Ryan, A., & Potashnikov, V. (2016), Exploring national decarbonization pathways and global energy trade flows: a multi-scale analysis, *Climate Policy*, 16 (sup1), S92-S109 (2016), (accessed 31 May 2018).

Other important characteristics of the model include:

- The objective to minimize cumulative discounted costs of the energy system (investment, O&M, fuels) over the time horizon, based on a discount rate of 3.5 per cent.
- The assumption of perfect foresight, for example any investment decision made in 2020 is made with an understanding of future system requirements out to 2100.
- Energy service demands that are responsive (elastic) to changes in price; so if prices increase, demands can reduce based on elasticity.
- BECCS is included in the model, and provides 'negative emissions'. This allows CO_2 emissions to be emitted at one point in time and then removed from the atmosphere later. In the case of BECCS, the removal is by combusting bioenergy and storing the CO_2 underground. This generates negative emissions based on the assumption that the bioenergy CO_2 would have been sequestered in the biosphere by regrowth.

Climate scenarios in TIAM-UCL

The 2°C scenarios in this paper are based on the TIAM-UCL modelling and are normative in nature. They consider a future temperature stabilization target as given, and assess cost-optimal scenarios for meeting that target. One example is the rapid phase-out of coal under the 2°C scenario; while this may not happen, the insight for decision-maker is that phasing out coal as rapidly as possible offers the least-cost pathway to 2°C, as it is the most carbon-intensive fossil fuel and as there are viable alternatives in the near term (at least in power generation).

Equity scenarios in TIAM-UCL

Modelling was undertaken using TIAM-UCL to explore the impacts of allocating extractive rights based on development need using the HDI rankings,[165] as described in Box 9 of the paper. The criteria for equity-based allocation were first proposed by Caney.[166] The regions of the model were first allocated to a group, based on the HDI index values of the countries within those regions (see Table 4). For regions that were a specific country e.g. China, this was straightforward. However, for some of the highly aggregated regions e.g. Africa and 'Other Developing Asia', this was problematic. It was therefore decided to use population-weighted scores to help determine what score to allocate to each given TIAM-UCL region.

Table 4: Allocation of TIAM-UCL regions to Human Development Index (HDI) groups

HDI group	HDI level (0–1)	TIAM-UCL regions
Low-medium human development (LMHD)	<0.7	Africa, India, Other Developing Asia
High human development (HHD)	0.7–0.8	Middle East, Mexico, South and Central America, China, Former Soviet Union
Very high human development (VHHD)	>0.8	Western Europe, Eastern Europe, UK, Canada, USA, Australia, Japan, South Korea

Source: Compiled by UCL (2018), based on TIAM-UCL regions and UNDP HDI rankings.

[165] UNDP, *Human Development Index (HDI) rankings*, available http://hdr.undp.org/en/composite/HDI (accessed 31 May 2018).
[166] Caney, S. (2016), 'Climate change, equity, and stranded assets', Oxfam America Backgrounder, https://www.oxfamamerica.org/static/media/files/climate_change_equity_and_stranded_assets_backgrounder.pdf (accessed 31 May 2018).

There are a few issues to note with the above categorization. Russia, which is in the HHD group, has a score at the upper end of the range at 0.798. Similarly, a number of the oil-rich Gulf states have HDI scores in the VHHD range but are included in the HHD group because of larger population countries in the Middle East having scores in the HHD range. This is important for such oil exporting countries that would otherwise have a lower extraction right allocation if they were in the VHHD group. Other Developing Asia also has a high diversity of HDI scores; however, the most populous countries such as Indonesia, Bangladesh and Pakistan have HDIs of less than 0.7. Finally, Eastern European countries all have scores in the VHHD range, except for Bulgaria and Romania, which have scores of 0.782 and 0.793, respectively.

Production levels determined under the 2°C scenario were then allocated to the HDI groups, with HDI1 allocated an increased production quota and HDI3 a lower production quota. The quota levels were originally determined based on a differentiated carbon tax on extraction, with a higher tax applied to HDI3 (thereby reducing production), with HDI2 incurring a tax level of 60 per cent of that for HDI3, and HDI1 only incurring a tax level of 10 per cent of the HDI3 tax level. The use of carbon tax mechanism is not intended as a politically viable mechanism with which to redistribute the remaining 'burnable' carbon budget, but rather as a means of allowing the model to endogenously determine the redistribution, without prescribing which type of fossil fuel production would be allocated where. This resulted in two scenarios: a low-quota case leading to a lower level of redistribution to HDI1, and a high-quota case with a higher level of redistribution to HDI1.

Annex III: Methodology for the Country Scenarios

The country-level models for Tanzania and Ghana in Chapter 3 were used to construct scenarios of future oil and gas production under different climate constraints, to provide insights on export potential, revenues and the use of fossil fuels in the domestic market.

Production and demand scenarios are projected for each year to 2045, starting from a base year of 2015. The models are split into two main parts 1) Production scenarios for oil (Ghana) and gas (Tanzania and Ghana), and 2) Demand scenarios for energy across all sectors, including fossil fuel consumption under different growth assumptions.

For both oil and gas, the scenarios of domestic production and demand are not linked. They are intended to allow for the comparison of very different supply and demand outlooks, and thus the identification of misalignments and risks. The implicit assumption is that if domestic production does not meet demand, imports make up the balance. Two further analyses were then developed to take into account revenues and emissions implications.

The approach to each is set out below:

1. Production scenarios

The production side of the model uses existing outlooks, from which scenario variants are then developed. While the same production 'cases' (high, base, low) were developed for each country, the detail is naturally different for each, and reflects the country's resource base and stage of production.

Tanzania

The three production scenarios for Tanzania focus primarily on the prospects for the development of Tanzania's offshore gas reserves. The scale of LNG operation in these scenarios is similar to that assumed in other reports from the IMF and NRGI.[167] In addition, all three scenarios assume the same level of onshore annual production of 157 million MMBtu, up to 2040, before declining. Each production case reflects the speed and scale of production, namely:

- *High* – Assumes four train LNG operation, each train at 5 MTPA, with production starting in 2023, in addition to existing onshore gas production.
- *Base* – Assumes two train LNG operation, each train at 5 MTPA, with production starting in 2023, in addition to existing onshore gas production.
- *Low* – A 'no final investment decision' case, where offshore production does not proceed due to a lack of investment, and only existing onshore gas production continues.

[167] Both considered illustrative projects with two to four LNG trains; the IMF uses scenarios of two and four LNG trains, NRGI uses three LNG trains; NRGI (2017), 'Uncertain Potential: Managing Tanzania's Gas Revenues', https://resourcegovernance.org/analysis-tools/publications/uncertain-potential-managing-tanzania-gas-revenues (accessed 31 May 2018); IMF (2016), *IMF Country Report No.16/254 United Republic of Tanzania Selected Issues.* Washington DC: IMF, https://www.imf.org/external/pubs/ft/scr/2016/cr16254.pdf (accessed 31 May 2018).

As the exact allocation of Tanzania's new offshore production to export and domestic markets remains unclear, two further variables were developed for the 'base' and 'high' production cases;

- *'Export led'* – Gives priority to exports, with an additional 20 per cent produced on top of the export volume for the domestic market.
- *'Domestic led'* – Produces additional volumes to the export level to meet domestic demand.

The assumptions, units and data sources used to construct the production scenarios are listed below:

Parameter	Unit	Value	Source
Onshore gas reserves (recoverable)	Tcf	4.6	TPDC (2015)
Offshore gas reserves (recoverable)	Tcf	28.3	IMF (2016)
LNG train capacity	MTPA	5	Songhurst (2014)
LNG capex	$/TPA	1,300	Songhurst (2014)
Upstream capex	$/BCF	27.8	Estimate based on IMF (2016)
Upstream opex	$/BCF	1.4	5% of capex
Export transport cost	$/MMBtu	3	IMF (2016)
Domestic onshore gas price	$/MMBtu	5.3–5.8	EWURA (2017)
Domestic offshore gas price	$/MMBtu	4	Author estimate
Domestic distribution costs	$/MMBtu	2	Author estimate

Sources: TPDC (2015), 'Oil and Gas Exploration – General Overview', Tanzania Petroleum Development Corporation, http://www.tpdc-tz.com/wp-content/uploads/2015/04/OIL-and-GAS-EXPLORATION.pdf (accessed 5 Dec. 2017); IMF (2016), *IMF Country Report No.16/254 United Republic of Tanzania Selected Issues*; Songhurst, B. (2014), *LNG Plant Cost Escalation,* Oxford: The Oxford Institute for Energy Studies, https://www.oxfordenergy.org/wpcms/wp-content/uploads/2014/02/NG-83.pdf (accessed 14 Dec. 2017); EWURA (2017), 'Subsidiary Legislation Supplement no. 17 to The Petroleum Act: The Petroleum (Natural Gas Indicative Prices) (Special Strategic Investments) Order, 2017', http://www.ewura.go.tz/wp-content/uploads/2015/03/Petroleum-Natural-Gas-Indicative-price-ORDER-2017.pdf (accessed 5 Dec. 2017).

Ghana

Only two of the three production pathways undertaken for Tanzania were developed for Ghana, given its more advanced stage of production, with existing oil and associated gas production, new natural gas production expected online in 2018, and further reserves under consideration. The production cases for Ghana focus primarily on the prospects for exports of crude oil, and the production of natural gas (both associated with the crude oil production, and non-associated) for the domestic market. The scenarios draw on previous projections from the Ghanaian government,[168] the World Bank,[169] and market analysts.[170]

Three main fields – Jubilee, TEN and Sankofa – are modelled. All produce crude oil, with Jubilee and TEN primarily producing associated gas, and Sankofa producing non-associated gas. The development of additional acreage – the Pecan and MTAB fields – is also considered in the 'high' case. The details of each production pathway are:

[168] Ghana Ministry of Petroleum (2016), 'Gas Master Plan, June 2016', http://www.petromin.gov.gh/sites/default/files/06-14%20GMP%20Updated.pdf (accessed 31 May 2018), Ghana Ministry of Petroleum (2016), 'Ghana Celebrates First Oil from the TEN Field', http://www.petromin.gov.gh/ghana-celebrates-first-oil-ten-field (accessed 31 May 2018).
[169] World Bank (2013), 'Energizing Economic Growth in Ghana: Making the Power and Petroleum Sectors Rise to the Challenge', http://documents.worldbank.org/curated/en/485911468029951116/Energizing-economic-growth-in-Ghana-making-the-power-and-petroleum-sectors-rise-to-the-challenge (accessed 31 May 2018).
[170] Ecobank (2016), 'Ghana Oil & Gas Upstream Outlook. September 2016', http://www.ecobank.com/upload/publication/20160921012446995A5RG4TAQ11/20160921012423860A.pdf (accessed 31 May 2018).

- *High* – As per the 'base' case below, this scenario includes additional development of the greater Jubilee area e.g. the MTAB projects and the Pecan field by the early-mid 2020s, which increases oil production (and associated gas) levels. Gas production levels for Sankofa are also estimated to be maintained for longer due to a more optimistic view concerning reserves.
- *Base* – Oil production is broadly aligned with World Bank projections, based on a profile that looks to maximize production in the next five years (towards 80 billion barrels). There is a similar expectation for gas, with Sankofa production in play by 2018, and is set to rise fast. As for all gas trajectories, blow down maintains production levels towards the end of the trajectory.
- *Low* – N/A for Ghana

It is assumed that all oil production is exported, and all gas production is used domestically. The assumptions, units and data sources used to construct the production scenarios are listed below:

Parameter	Units	Value	Source
Oil			
Field reserve levels	Mn bbl	1,490	Ghana Ministry of Petroleum, 2016 (2016); Ghana Ministry of Finance (2015); Eni (2013)
Field-level breakeven prices	$/bbl	20–45	Ecobank (2016)
Government revenue share (approx.)	%	60	World Bank (2013)
Gas			
Reserve levels	TCF	2.2	Ghana Ministry of Petroleum, 2016
Gas-to-oil ratio (GOR), for associated gas*	cf/bbl	1,000	Ghana Ministry of Petroleum, 2016
Re-injection rate (gas recouped at end of production – 'blow down')*	%	20	Ghana Ministry of Petroleum, 2016
Production capacity (Sankofa)	MMcfd	160	World Bank, 2013
Cost (Sankofa)	$/MMBtu	8–10	Ghana Ministry of Petroleum, 2016; World Bank, 2013
Cost (assoc. gas)	$/MMBtu	2–3	Ghana Ministry of Petroleum, 2016; World Bank, 2013

* Estimates for Jubilee, also used for other associated gas production in the absence of field specific information
Sources: Ghana Ministry of Petroleum (2016), 'Gas Master Plan, June 2016'; Ghana Ministry of Petroleum (2016), 'Ghana Celebrates First Oil from the TEN Field'; Ghana Ministry of Finance (2015), '2015 Reconciliation Report on the Petroleum Holding Fund', http://www.mofep.gov.gh/sites/default/files/reports/petroleum/2015%20Reconciliation%20Report%20on%20the%20Petroleum%20Holding%20Fund.pdf (accessed 10 Dec. 2017); Eni (2013), 'Eni successfully drilled first oil delineation well of the Sankofa East oil discovery in offshore Ghana', https://www.eni.com/docs/en_IT/enicom/media/press-release/2013/01/PR_Sankofa_ENG.pdf (accessed 6 Dec. 2017); Ecobank (2016), 'Ghana Oil & Gas Upstream Outlook. September 2016'; World Bank (2013), 'Energizing Economic Growth in Ghana: Making the Power and Petroleum Sectors Rise to the Challenge'.

2. Demand scenarios

The demand projections were based on 2015 energy demand figures and used two sets of drivers of demand. The first includes economic growth, population change, and the energy balance and intensity of different economic sectors.[171] The models used national projection estimates (detailed below), which can be adjusted to explore higher or lower assumptions. The second set of drivers mainly consist of the rate of energy efficiency improvement across different sectors (with annual improvements in energy intensity

[171] IEA (2016), World Energy Balances: World Extended Energy Balances, 1960–2015, International Energy Agency, (Data downloaded from UK Data Service), https://www.oecd-ilibrary.org/energy/data/iea-world-energy-statistics-and-balances/extended-world-energy-balances-edition-2016_5138d8dd-en (accessed 31 May 2018).

in end-use sectors ranging from 0.25 per cent under BAU to 0.5 per cent in the 'green' trajectory). These scenarios consider energy demand across all sectors and fuels, not only fossil fuels. Two demand trajectories were developed for each country – a 'business as usual' case, and a 'green' case.

Tanzania

For Tanzania the default expectation for economic growth is 7 per cent GDP in the near term and 5 per cent in the long-term.[172] The country's population is expected to grow at an average 2 per cent annually over the model period based on Tanzanian government projections.[173] The impact of GDP growth on the energy consumption of commercial sectors is based on the assumed energy intensity per production factor, calibrated based on the 2014 energy balance.[174] Two energy demand cases are developed, as follows:

- *Business-as-usual* – Gas shares across different sectors, not absolute levels, are based on national gas plan assumptions contained within national plans.[175]
- *Green* – This scenario assumes a greener system, with a strong focus on non-biomass RE and lower levels of fossil fuel use.

The shares of energy consumption across all sectors, including power generation, provide an insight into how different energy sources aggregate across the sector.

Share of total energy consumption by type	**2015 (%)**	**2045 (%)**	
		BAU	Green
Gas	4	35	18
Coal	0	13	0
Hydro	1	3	9
Renewable (excl. hydro and bioenergy)	0	3	45
Oil	10	8	4
Bioenergy	84	39	23

The contribution to electricity generation by type across the scenarios is provided below.

Shares of electricity generation by source	**2015 (%)**	**2045 (%)**	
		BAU	Green
Gas	44.7	38.0	10.0
Coal	0.0	30.0	0.0
Hydro	41.8	25.0	35.0
Renewables – Solar Off Grid	0.8	5.0	25.0
Renewables – Solar On Grid	0.0	1.5	15.0
Renewables – Wind	0.0	0.5	15.0
Oil	12.7	0.0	0.0

[172] Government of Tanzania (2016), *Power System Master Plan 2016 update*, Ministry of Energy and Minerals, http://www.ewura.go.tz/wp-content/uploads/2017/01/Power-System-Master-Plan-Dec.-2016.pdf (accessed 31 May 2018).
[173] Population and Housing Census (2014) shows an annual average growth of 2.7 per cent between 2002 and 2012, 'Tanzania National Bureau of Statistics (2014) Basic Demographic and Socio-Economic Profile', http://www.nbs.go.tz/nbstz/index.php/english/statistics-by-subject/population-and-housing-census/249-2012-phc-tanzania-basic-demographic-and-socio-economic-profile (accessed 31 May 2018).
[174] IEA (2014), 'Energy Balances of Non-OECD Countries: Summary Energy Balances, 1971–2013', UK Data Service, DOI: http://dx.doi.org/10.5257/iea/ebnon/2014 (accessed 31 May 2018).
[175] Government of Tanzania (2016), Natural Gas Utilization Master Plan, https://www.jamiiforums.com/attachments/oil-and-gas-masterplan-pdf.495398/.

Ghana

For Ghana, the GDP rates were based on a near term rate of 7 per cent, declining to 5 per cent by 2045. Ghana's annual average GDP growth rate from 2000 to 2011 was 6.4 per cent. A central 2 per cent estimate was used for population growth, as per World Bank data, and is assumed to stay constant.[176] Two energy demand scenarios were developed, as follows:

- *Business-as-usual* – Reflects a continued use of fossil fuels, in particular gas use based on national outlook.[177]
- *Green* – This scenario assumes a greener system, with a strong focus on non-biomass RE and lower levels of fossil fuel use.

The energy consumption shares across all sectors including power generation provide an insight into how the different shares assumed across sectors aggregate.

Share of total energy consumption by type	2015 (%)	2045 (%)	
		BAU	Green
Gas	16	30	13
Coal	0	0	0
Hydro	8	5	17
Renewable (excl. hydro and bioenergy)	0	4	43
Oil	42	49	21
Bioenergy	34	12	5

The contribution to electricity generation by type across the scenarios is provided below.

Shares of electricity generation by plant type	2015 (%)	2045 (%)	
		BAU	Green
Gas	38.1	60.0	10.0
Coal	0.0	0.0	0.0
Hydro	49.8	25.0	50.0
Renewables – Solar Off Grid	0.1	5.0	15.0
Renewables – Solar On Grid	0.0	1.5	15.0
Renewables – Wind	0.0	0.5	10.0
Oil	12.0	8.0	0.0

[176] World Bank data shows that the population growth rate for Ghana sits at just over 2 per cent. World Bank Group (2016), 'Population growth (annual %)', https://data.worldbank.org/indicator/SP.POP.GROW (accessed 31 May 2018).
[177] Ghana Ministry of Petroleum (2016), Gas Master Plan, June 2016, http://www.petromin.gov.gh/sites/default/files/06-14%20GMP%20 Updated.pdf.

3. Revenues

Commodity price information is estimated using projections from the IEA and IRENA,[178] complimented with modelling from TIAM-UCL. For both countries, as outlined in the main report, export revenue calculations are based on the following formula:

([Export level] × [Market price] - [Total production & transport costs]) × [Government share]

The price inputs are based on figures for market demand and prices in the TIAM-UCL model, which were cross-checked against IEA projections. Prices are not discounted. Gross revenues are charted under three climate scenarios presented in Chapter 2 of this paper:

- *An NDC scenario* – equivalent to the current NDC commitments (resulting in roughly a 3.5°C temperature rise);
- *A 2D scenario* – equivalent to a 2°C carbon budget; and
- *A No CCS scenario* – where CCS fails to play their expected role within a 2°C scenario and the available carbon budget is effectively halved.

Table 5: Price assumptions under different climate scenarios

			2015	2020	2025	2030	2035	2040	2045	2050
Oil	NDC	$/brl	51	79	95	111	118	124	131	137
	2D	$/brl	51	73	70	66	65	64	63	61
	2D No CCS	$/brl	51	73	58	54	53	52	50	49
Gas	NDC	USD/Mbtu	10.5	9.6	10.75	11.9	12.15	12.4	12.6	12.8
	2D	USD/Mbtu	10.5	8.9	10.4	11.0	11.1	10.7	10.9	10.7
	2D No CCS	USD/Mbtu	10.5	8.9	9.0	9.0	8.2	7.4	6.8	6.2

Source: TIAM-UCL, IEA (2018).

Tanzania

For Tanzania, government share estimates are based on an analysis of the current revenue sharing agreement,[179] following a similar approach to the IMF.[180] Actual revenue would depend on a range of factors, including profit sharing with the IOC, tax regime, production level and the international market price.[181] A further set of estimates include the revenue take from the domestic market price, and added to the above export revenue calculation. However, at present, the costs of bringing offshore gas to the domestic market are unclear and a point of political discussion in-country.

Gas revenues are presented in four ways (the first is primarily used in this paper); 1) revenues raised from export sales; 2) revenues raised from export sales, net of production costs; 3) total revenues

[178] IEA and IRENA (2017), *Perspectives for the energy transition: Investment needs for a low-carbon energy system*, March 2017, http://www.irena.org/publications/2017/Mar/Perspectives-for-the-energy-transition-Investment-needs-for-a-low-carbon-energy-system (accessed 31 May 2018).
[179] TPDC (2013), *Model Production Sharing Agreement Between The Government of the United Republic of Tanzania and Tanzania Petroleum Development Corporation and ABC Ltd for Any Area 2013,* Dar es Salaam: Tanzanian Petroleum Development Corporation, http://www.eisourcebook.org/cms/Nov%202013/Tanzania%20Production%20Sharing%20Agreement%202013.pdf (accessed 31 May 2018).
[180] IMF (2016), *IMF Country Report No.16/254 United Republic of Tanzania Selected Issues.* (accessed 31 May 2018).
[181] Kyle, I. (2017), 'Assessing the Value of Natural Gas Reserves for the Equitable Sharing of Fossil Fuel Extractive Rights in a Climate Constrained World', MSc thesis under UCL EPEE programme.

raised from export and domestic sales; and 4) total revenues raised from export and domestic sales, net of production costs.

Ghana

For Ghana, export oil revenues are set out in three ways (the first is primarily used in this paper); 1) total revenue raised from crude exports; 2) revenues raised from export net of (breakeven) costs; and 3) revenues raised from export net of (breakeven) costs and import bill (for oil products).

Gas revenues are presented in two ways; 1) revenues raised from domestic sales, and 2) revenues raised from domestic sales, net of production costs.

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